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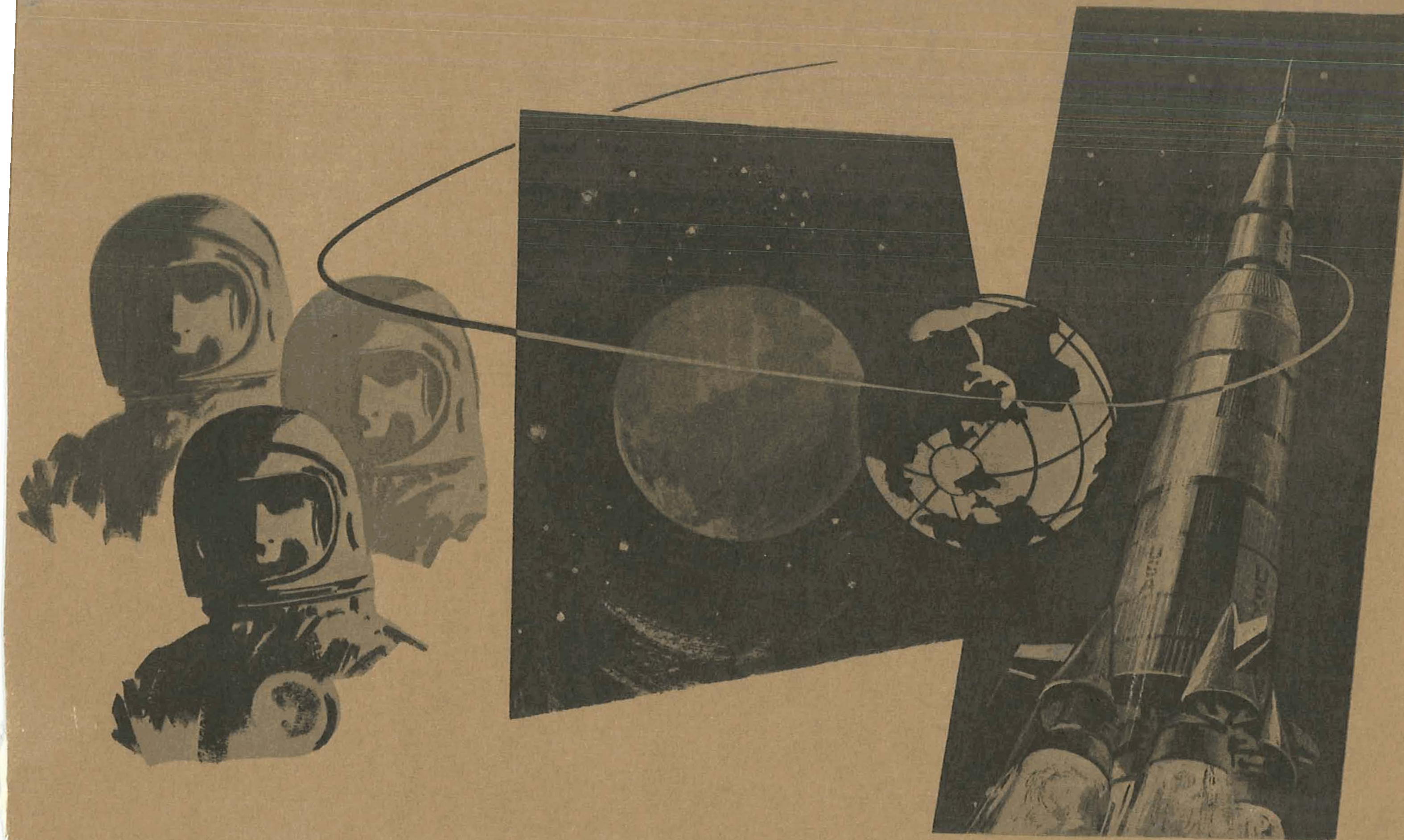

DOUGLAS REPORT DAC-56567

VENDOR AWARENESS PROGRAM

JUNE 1967

DOUGLAS
MISSILE & SPACE SYSTEMS DIVISION

VENDOR AWARENESS PROGRAM

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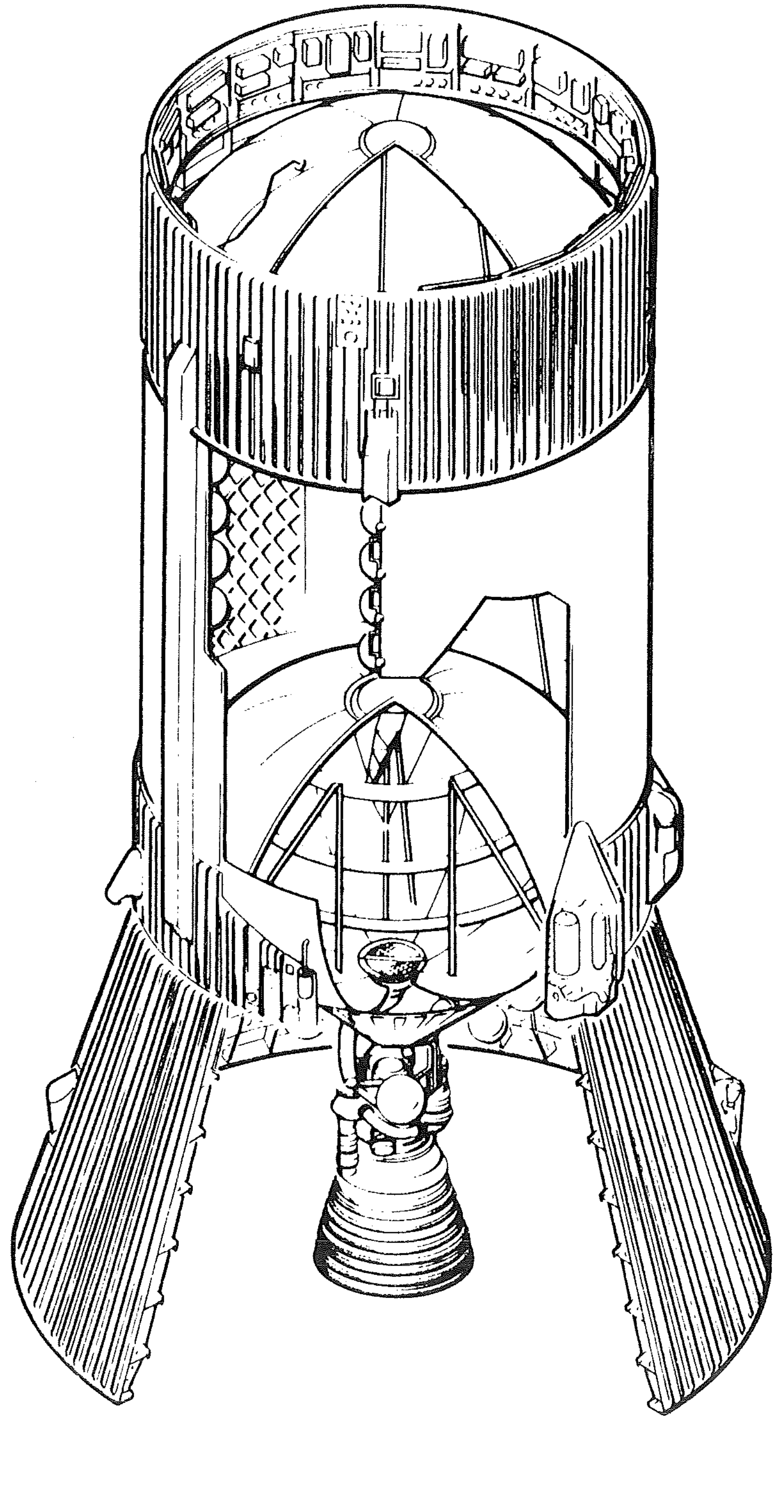
VENDOR AWARENESS



ABSTRACT

The Saturn Vendor Awareness Meetings conducted by the Douglas Missile and Space Systems Group during the months of April and June 1967 were held for the purpose of making Douglas subcontractors, engaged in the Saturn program effort, aware of the necessity of providing, maintaining, and enforcing tight quality control procedures.

The meetings were attended by representatives of approximately fifty companies and corporations who are under contract to Douglas to provide parts and components which are used in the Douglas S-IVB stage.

Members of the Douglas Management Team and the NASA Saturn I-1B Program Manager addressed the meetings on a variety of subjects intended to focus attention on, and make the subcontractors aware of, the very urgent need to supply parts and components that fulfill the no-fail criteria of their respective contracts.

DESCRIPTORS

Parts
Quality
Vendors/Subvendors
Flight Critical Parts
Hazardous Parts
Human Error
Inadequate Work Performance
Product Quality
Inspection
Failure Effects
Failures
Motivation/Awareness
Implementation Discrepancies
System/Procedure

PREFACE

Two Saturn Vendor Awareness Meetings were conducted at the Douglas Missile and Space Systems Group Huntington Beach Facility on April 25 through 28, 1967, and June

The meetings were arranged by Mr. C. R. Able, Group Vice President, Missile and Space Systems Group at the request of Dr. Wernher von Braun, Director, George C. Marshall Space Flight Center.

Purpose of the meetings was to focus attention on the number of significant failures that have been encountered in the Saturn Program during recent months, and to emphasize the importance of tight quality control procedures and their enforcement.

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SECTION 1

1. INTRODUCTION

This document was prepared by Douglas Aircraft Company, Inc., Missile and Space Systems Group, Huntington Beach, California, in response to a request from National Aeronautics and Space Administration (NASA) Marshall Space Flight Center (MSFC), Huntsville, Alabama. The purpose of this report is to document in report form two "Vendor Awareness" presentations made at the Space Systems Center during the months of April and June 1967. These presentations were prepared in response to a letter from NASA/MSFC, to create among subcontractors and vendors an atmosphere of "awareness" of the criticality of all Saturn flight critical items, and to emphasize the impact of flight critical items failures on the overall Saturn/Apollo Program.

All data presented in discussion and vugraph form at the presentations have been converted, where possible, to Santa Monica Report format, and are presented in the following sections.

SECTION 2

2. PRESENTATION INTRODUCTION - APRIL MEETING

Prefacing the introduction were excerpts from two letters, the first from Dr. Wernher von Braun, in which he expressed his concern relative to the failures experienced as the Saturn Program, quote:

> "During the past few months the Saturn program has encountered a number of significant failures which has caused me to become seriously concerned. I am even more concerned about the future when we will be manning our flights. These instances have resulted from various causes, usually traceable to a human error or inadequate manufacturing, quality control or test procedures. I am aware that in each case our project manager and the contractor have taken the necessary steps to remedy the situation and prevent recurrence. The area I am particularly concerned about at the present time is the quality of products delivered to you by your vendors and subvendors."

The second excerpt was a response to Dr. von Braun from a letter written by Mr. C. R. Able, quote:

> "In the area of vendor and subvendor motivation/awareness programs, we believe that program benefits can be derived. Accordingly, we plan to seek methods of reaching our vendors individual employes by acquainting them with the critical significance of their activity to reduce the possibility of human error or inadequate work performance. We also contemplate identifying a "single-point responsible executive" at each critical vendor or subvendor who will be made fully aware of the role his products play in the overall program. Since we plan to inform this individual of the full consequences of a failure of his product, we believe that he will be motivated to play a vital role in educating his employes involved in critical tasks with respect to a keen awareness of the consequences that could arise from a mistake on their part. Incidentally, we also feel that the responsible executive will be further motivated when we point out the fact, as demonstrated by the board of inquiry investigation of the stage 503 incident, that a combined NASA/Douglas investigation will find the source of any hardware failure."

Following presentation of the quoted passages, the introduction continued with the definitive statements given below

a. Why are we here?

b. The Nature of the Problem.

c. How you can help.

d. What's in it for you?

e. What happens if we fail?

f. Planned follow-on effort.

In answer to the above, the following was pointed out:

a. Why are we here?

   We are here because there have been serious problems, many of which start with vendors and subvendors. You are the person who can do the most good. Problem avoidance is better than problem solving.

b. The nature of the problem

   The nature of the problem is compounded of several problem areas:

   1. Human error
   2. Inadequate manufacturing
   3. Inadequate quality control
   4. Inadequate reject/accept procedures
   5. Lack of understanding of design/mission intent
   6. Inability to detect relationship of series of "minor problems"
   7. Inadequate discrepant material disposition procedures

c. How can you help?

   1. Know what a failure of your product could do
   2. Know the soft spots in your shop
   3. Know the soft spots in your suppliers
   4. Bore in, and shore up weak areas
   5. Share knowledge of problems with us
   6. Spot check delivered hardware records
   7. Submit change requests
   8. Be assured that discrepant material procedures are properly implemented

- Effective material review board and material review control center
- Procedures are well written
- Procedures are well understood
- Procedures are well implemented -- and followed through
- Technical disposition plus determination of "true cause" of failures

d. What's in it for you?

1. Avoidance of image loss
2. Avoidance of board of investigation team
3. Avoidance of big traumatic experience

e. What happens if we fail?

1. S-IVB Stage 503 experience
2. SA 204 experience
3. Another experience
4. Loss of national goals

f. Planned follow-on efforts

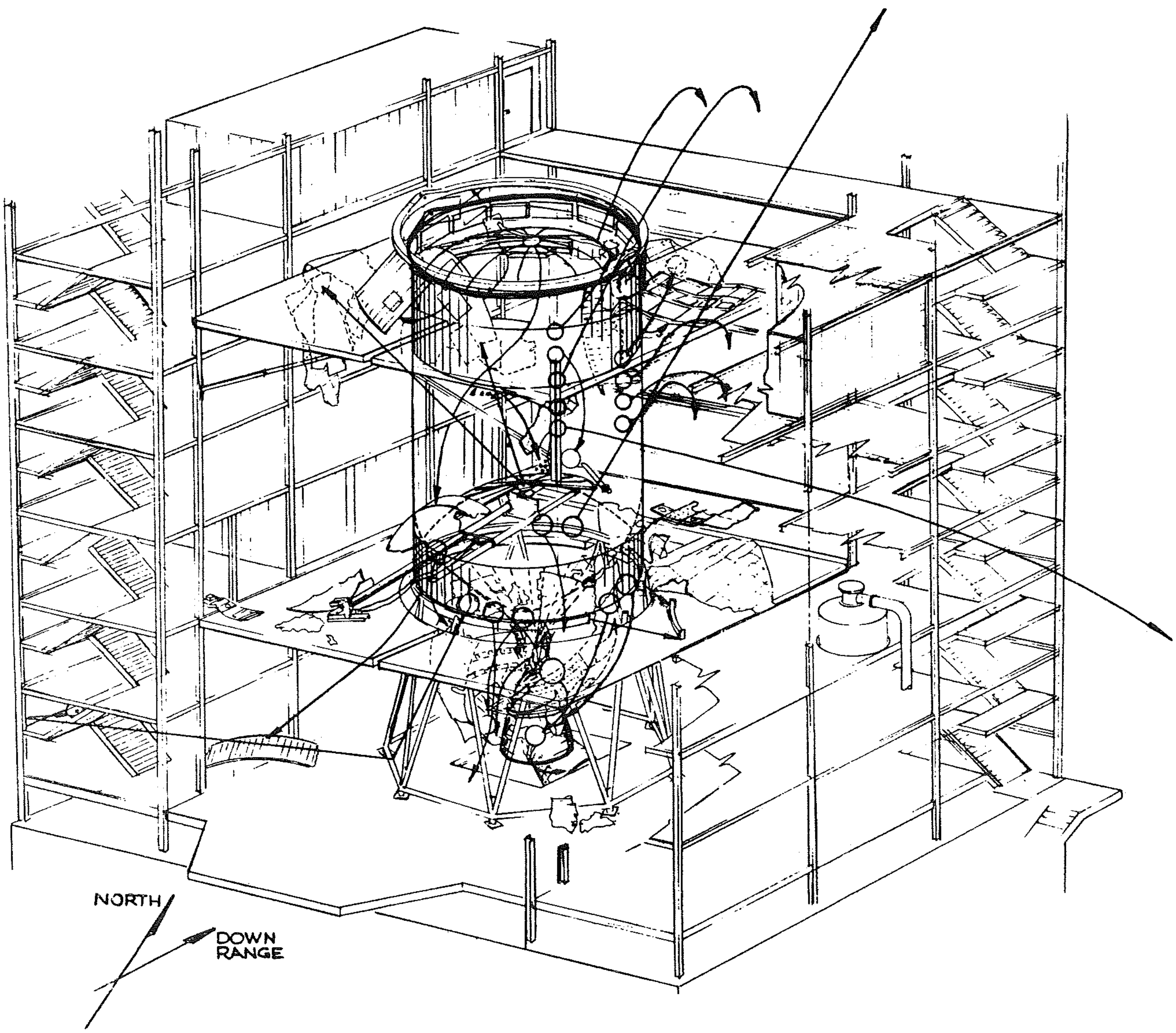
1. Douglas to review adequacy of requirements to vendors
   - Design intent requirements
   - Procurement requirements
   - Quality assurance requirements
2. Fall out of Douglas effort to vendors
   - Revised specifications
   - Revised procurement instructions
   - Revised QA procedures
3. We will solicit your help for reasonableness and effectiveness
   - Contractual adjustments may be required
   - Your thoughts on cost effectiveness will be important inputs

Current and follow-on effort is presented in the following chart.

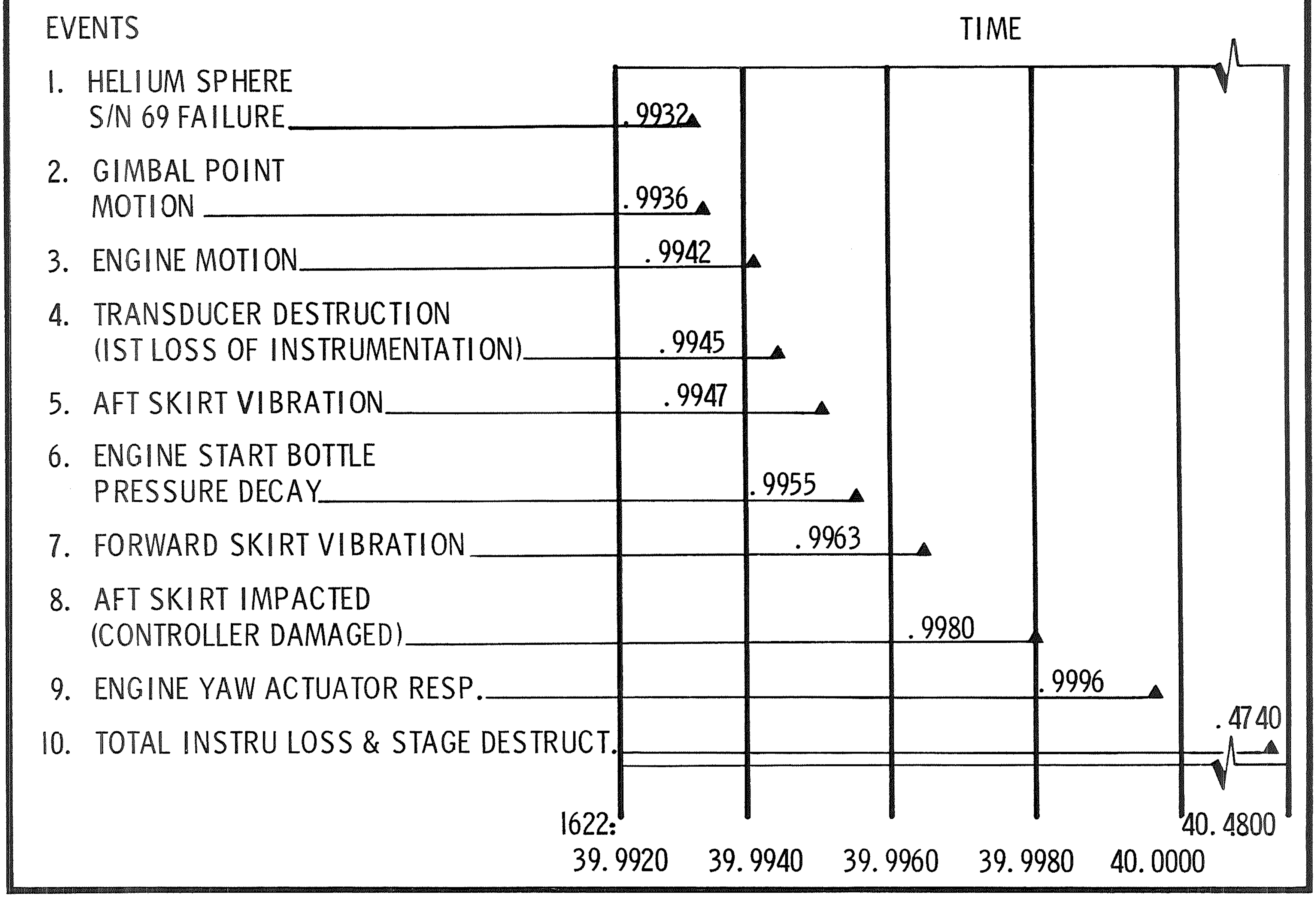
2.1 S-IVB/V-503 Stage Incident

2.1.1 Narration of Investigation

The Assistant to Senior Director, Operations, provided a concise narration of the sequence of events that lead to destruction of the S-IVB/V-503 stage as depicted in the following chart. The chart depicts the movement of parts fragmented during destruction of the stage.



S-IVB/V-503 STAGE INCIDENT SEQUENCE OF EVENTS



2.1.2 Non-specified Weld Wire

The following charts present a chronological sequence of events pertaining to non-specified weld wire, plus supporting documentation, from 17 March 1965 through 29 December 1965.

NON-SPECIFIED WELD WIRE SEQUENCE OF EVENTS

DATE	EVENT	SUPPORTING DOCUMENTATION	EXHIBIT NUMBER DAC-56531
3-17-65	PROCUREMENT OF 6AL4V,062, WELD WIRE	PO# 11010	A
3-22-65	CERTIFICATION FOR WELD WIRE PER PO #11010 IDENTIFIED COMMERCIAL PURE TITANIUM WIRE.	CERTIFICATE OF TEST FOR PO #11010 IDENTIFIED AS BUNDLE #975	A
7-24-65	SOLUTION HEAT TREAT & PARTIAL AGING OF FORGED RINGS FOR WELD TEST RING (WTR) #3	PO #11997	C
		CERTIFICATION NO. #LA89781	C
8-10-65	FABRICATION OF WTR #3 USING NON-SPECIFIED WELD WIRE. (BUNDLE #975)	SHOP ORDER 17142 DATED 8-10-65	B
8-17-65	FINAL AGE AT 1000° F OW WTR #3	PO #12219	E
		CERTIFICATION NO. #LA90960	F
9-27-65	DELIVERY OF SIX (6) TEST SPECIMENS FOR WTR #3 TO A TESTING LABORATORY	PO #12586	G
10-8-65	LAB CERTIFICATION FOR WTR #3 DOCUMENTING TENSILE STRENGTH OF 102,150 PSI MINIMUM REQUIREMENT IS 130,000 PSI.	LAB TEST REPORT #H-755	H

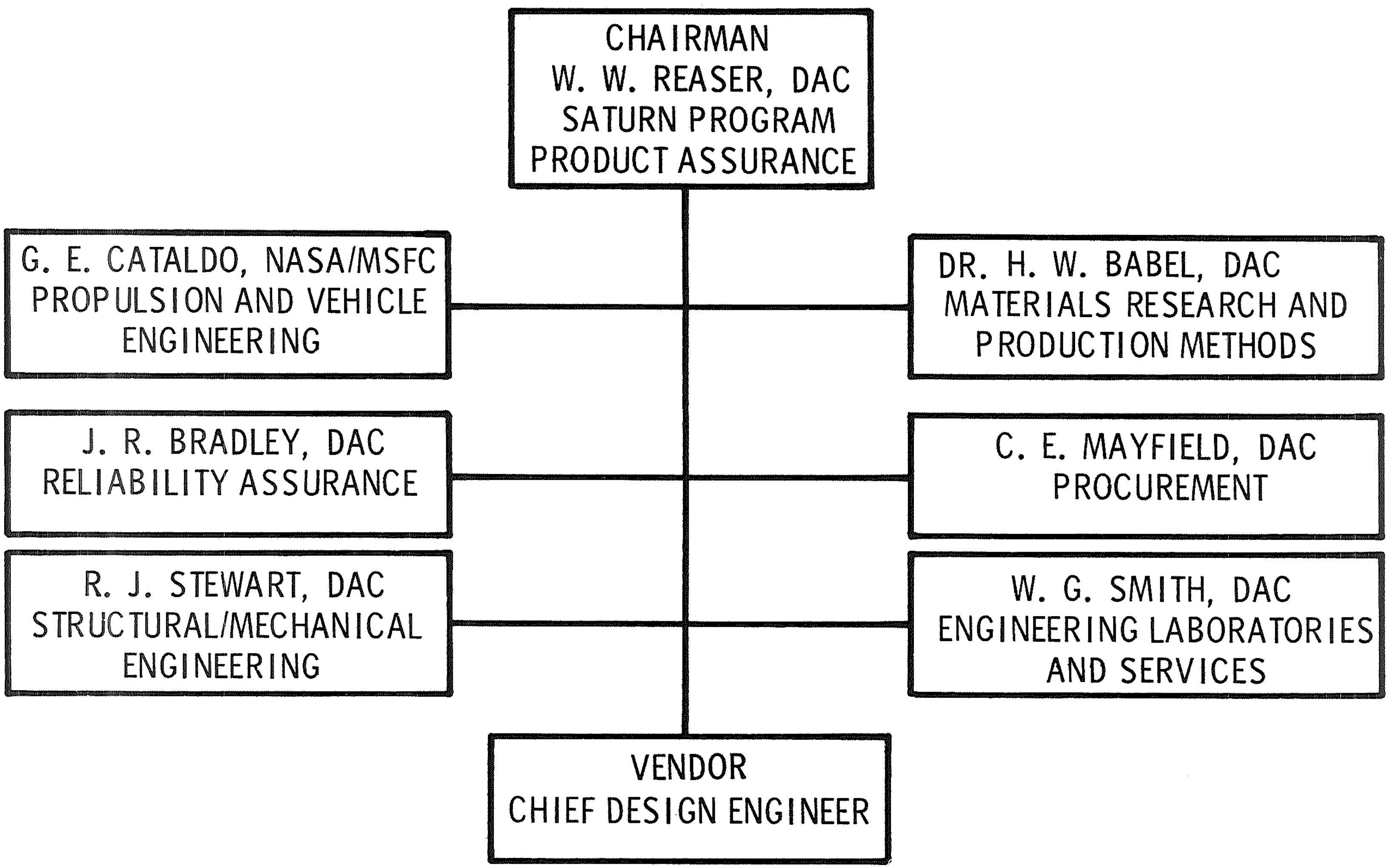
NON-SPECIFIED WELD WIRE SEQUENCE OF EVENTS

DATE	EVENT	SUPPORTING DOCUMENTATION	EXHIBIT NUMBER DAC-56531
10-13-65	4 OF 6 REMAINING TEST SPECIMENS RETURNED FROM LAB TO VENDOR. SENT TO ANOTHER VENDOR FOR AGING (2ND AGING PROCESS).	PO #12743	J
10-14-65	CERTIFICATION OF AGING FOR 2 1/2 HRS AT 1000° F & AIRCOOLED.	CERTIFICATION NO. #LA93821	K
10-25-65	SOLUTION HEAT TREAT & PARTIAL AGING OF FORGED RINGS	PO #12847	M
		CERTIFICATION NO. #LA94400	N
11-19-65	FABRICATION OF 2ND WTR AGAIN IDENTIFIED AS WTR #3, USED SPECIFIED WELD WIRE. (BUNDLE #984)	SHOP ORDER 17142 DATED 11-19-65	L
12-6-65	FINAL AGE AT 1000° F OF 2ND WTR AGAIN IDENTIFIED AS WTR #3.	PO #13254	P
		CERTIFICATION NO. #LA96508	Q
12-8-65	(1) SPECIMEN OF 2ND WTR, AGAIN IDENTIFIED AS WTR #3, TO LAB FOR TEST.	PO #13279	R
12-29-65	LAB CERTIFICATION FOR 2ND WTR, AGAIN IDENTIFIED AS WTR #3, DOCUMENTING TENSILE STRENGTH OF 164,050 PSI.	LAB TEST REPORT NO. #H-3082	S

2.2 Official Investigation Team

The official investigating team chosen to investigate the 503 stage incident is given in the following chart.

OFFICIAL INVESTIGATION TEAM



CURRENT AND FOLLOW-ON EFFORT					
VEHICLE	DEFINITIZED			NEGOTIATED	PROPOSED PROCUREMENT
	LAUNCHED	COMPLETED	IN WORK		
S-IB EARTH ORBIT	3	7	2	4	12
S-V EARTH ORBIT LUNAR MISSIONS	0	4	2	9	10

SECTION 3

3. VENDORS FLIGHT CRITICAL ITEM COMPONENTS

Following is a breakdown by category of vendor flight critical items, with a brief description of the function and criticality of each component.

3.1 S-IVB Propulsion System

The single burn S-IB/S-IVB stage propulsion system utilizes a bipropellant liquid oxygen-liquid hydrogen J-2 engine to boost the Apollo spacecraft into earth orbit on the S-IB missions and to boost the Apollo spacecraft into earth orbit and later into a translunar orbit on the Saturn V missions. Stage systems incorporate provisions for separation from the S-IB booster or the S-II booster, attitude control, stage guidance and conditioning of propulsion system as required for normal engine start and burn. Included in the S-IVB propulsion systems are separate LOX and Hydrogen tank pressurization, venting, fill, engine feed and chilldown systems.

Mounted on the side of the stage are two auxiliary propulsion system modules which are used to provide roll control during the powered phases of the S-IVB flight, and to provide pitch, roll, yaw attitude control during orbital coast phase of the flight. On the S-V version of the APS, propellant settling capability isincorporated, as required, for orbital venting and second main engine restart.

3.1.1 Filtration - Mechanical

Solid particle contamination (dirt) is the deadly enemy of space vehicles. Many malfunctions have, in the past, been attributable to lack of cleanliness. The Apollo Program cannot tolerate unclean systems, whether they be gaseous, liquid, electrical, or propellant.

The primary approach to uncontaminated systems is cleanliness before installation and then maintaining this cleanliness by careful protection and operation thereafter.

The secondary approach is to add filtration, at key points, in case some solid-particle contamination did get into the vehicles systems. Experience has shown that this backup approach is still necessary and vital to success. Being a backup does not detract from the important role played by filters. These filters must withstand pressures, temperatures, etc., as required and must trap any contamination which may find its way to a filter.

Filters have even trapped solid water or solid nitrogen which was present in a pressure system. They are important to success.

3.1.2 Chilldown Recirculation System (Figure 1)

Chilldown conditioning of the engine pumps, inlet ducting and the engine hardware for engine start is accomplished by separate LOX and LH_2 chilldown systems. The purpose of the recirculation system is temperature stabilization of the propellants and the engine pump inlet hardware in order to meet NPSH requirements of the engine pumps. Propellants from each tank are recirculated through the feed systems and return lines by chilldown pumps, check valves, prevalves, shutoff valves and ducting control, and route the fluids to perform the chilldown function.

- FAIRCHILD/HILLER CORPORATION (Stratos Western)

Chilldown Shutoff Valve, Part Number 1A49965 (Figures 1 and 2)

Fairchild/Hiller supplies this component. If these valves fail to open, it would not be possible to provide the prestart temperature conditioning and, therefore, would prevent proper starting of the engine.

- PESCO PRODUCTS (Division of Borg-Warner Corporation)

LH_2 and LOX Chilldown Motor Pumps, Part Numbers 1A49421 and 1A49423 (Figure 2)

These pumps supply the pressure to force the propellants through the feedlines and engine, and the return lines back into the tanks. Failure of these pumps to operate properly on command would result in improper chilling of the engine. This would prevent the engine from starting and could cause the engine to destroy itself and the stage during the start sequence.

- PARKER AIRCRAFT COMPANY

<u>Chilldown Swing Check Valve, Part Number 1A49964 (Figure 1)</u>

The purpose of this valve is to prevent backflow through the chilldown pump, which could cause a failure of the electrical inverter which supplies the pump. Failure of the inverter would prevent chilldown for the second engine start. This could mean that the main engine could not be started, with the resultant abortion of the mission or improper chilldown and possible destruction of the stage.

- CONSOLIDATED CONTROLS

<u>Switch, Pressure, High Performance, Part Number 1B52624 (Figure 3)</u>

Calips (calibrationable) pressure switches are pressure-sensitive, single-pole, double-throw electrical switching devices. The Calips type switches are utilized on the Saturn V version of the Saturn stages.

The Calips pressure switch employs two pressure ports, each isolated from the other. The additional port provides for remote checkout without disconnecting or contaminating the primary pressure system. The test port-pressure settings are calibrated during manufacture of the switch, to provide an accurate indication of the system port-pressure settings. Pneumatic pressure applied to the test port functionally operates the pressure switch mechanism in the same manner as pressure applied to the system port. Test port operation is not affected by residual pressure (up to 95 per cent deactuation) in the system port cavity.

The Consolidated Controls Corporation pressure switch utilizes a mass balancing system to counteract effects of vibration, and a single Belleville spring to provide snap-action on increasing and decreasing pressures. The electrical element is a Honeywell microswitch built to Consolidated's specifications. The Calips feature is provided by two diaphragms on the low-pressure unit and by two bellows on the high-pressure unit.

Due to the fact that the pressure switches are utilized to control main tank pressure, the loss of these pressure switches would result in abort of the mission.

- J. C. CARTER COMPANY

Ambient Temperature Helium Check Valve, Part Number 1B51361

This valve is used to prevent backflow of helium from the LH_2 tank repressurization system storage spheres. Leakage of helium gas to the atmosphere through these check valves could result in premature loss of tank pressurization supply, and possible mission abort. See figure 3.

Cold Helium Check Valve, Part Number 1B40824

This valve is used to prevent backflow of helium gas in the O_2/H_2 burner propellant tank repressurization system. Hangup of the check valve poppet could impede pressurization flow and could also allow backflow of LH_2 vapors into the LOX tank pressurization system or backflow of LOX vapors into the LH_2 tank pressurization system. See figure 2.

- HYDRA ELECTRIC COMPANY

Switch, Pressure, Part Number 1B52623 (Figure 3)

Calips (calibrationable) pressure switches are pressure-sensitive, single-pole, double-throw electrical switching devices. The Calips type switches are utilized on the Saturn V version of the Saturn Stages. See figure 4.

The Calips pressure switch employs two pressure ports, each isolated from the other. The additional port provides for remote checkout without disconnecting or contaminating the primary pressure system. The test port pressure settings are calibrated during manufacture of the switch, to provide an accurate indication of the system port-pressure settings. Pneumatic pressure applied to the test port functionally operates the pressure switch mechanism in the same manner as pressure applied to the system port. Test port operation is not affected by residual pressure (up to 95 percent deactuation) in the system port cavity.

The electrical switch elements are integral with the actuator mechanism, thereby eliminating the necessity for an additional electrical switching device. The Calips feature is provided by two diaphragms on all units.

Due to the fact that the pressure switches are utilized to control main tank pressure, the loss of these pressure switches would result in abort of the mission.

- CALMEC MANUFACTURING COMPANY (Division of Ametek)

Cold Helium Solenoid Control Valve, Part Number 1B43660

This valve is utilized to control the flow of repressurization helium to the propellant tank prior to second J-2 engine start on the Saturn V version of the S-IVB stage. Failure of these valves to respond to command could result in a lack of LH_2 tank repressurization and an inability to restart the engine. Helium gas leakage to the atmosphere through one of these valves could result in premature depletion of the repressurization control supply. See figure 4.

- CALMEC MANUFACTURING COMPANY (Division of Ametek)

Fuel Tank Pressurization Umbilical Disconnect, Part Number 7851861 (Figure 5)

The umbilical disconnect is the ground supply connection to the stage for prepressurizing the LH_2 tank prior to stage liftoff. Improper separation at liftoff would cause damage to the stage which could propagate due to aerodynamic forces during flight. This disconnect also provides a shutoff or check valve function which is redundant with other system check valves. Leakage during booster flight could cause loss of prepressurization gas and lack of NPSH at engine start resulting in mission abort.

- ADEL (Division of General Metals Corporation) (Vinson)

Fuel Tank Pressurization Control Module, Part Number 1B55200

This module contains a check valve, two solenoid-operated valves and orifices. This module controls the flow of gas coming from the engine or the ground umbilical supply to maintain the LH_2 tank pressure between predetermined limits, to provide adequate NPSH for engine operation. Improper operation of the solenoid valves would cause either too high or too low a rate of tank pressurization. Too high a rate of pressurization would cause the relief valves in the main tank to operate, and too low a rate of operation would allow the tank pressure to fall below acceptable inlet engine condition, thereby causing engine malfunction. See figure 4.

- AIRCRAFT POROUS MEDIA

Cold Helium Filter, Part Number 1B43659

This filter is used in the O_2/H_2 burner repressurization system to protect downstream orifices and components from contamination. Failure of these filters to contain contamination could result in plugged orifices downstream, or could result in malfunctioning components. Either of these could result in failure to repressurize the propellant tanks and thereby prevent proper engine restart. See figure 11.

- FREBANK CO.

Switch, Medium Pressure, Part Number 7851830 (Typical)

Other Part Numbers, 1A67002, 1A67005, 7851847, 7851860 (Figure 3)

S-IB vehicles use two types of Frebank (single diaphragm) pressure switches. One type provides direct conoseal mount to propulsion system modules, while the other provides a four-footed mount requiring a separate pressure line. The foot mounted unit is an S-IV type pressure switch of improved design. Pressure switches are located in either the aft section (thrust structure) or the forward section (tank dome), depending upon the pressure control system in which the switch is used.

All single diaphragm pressure switches, regardless of mounting method, are pressure-sensitive electrical switching devices utilizing multiple Belleville Springs which provide "snap" response to actuation or deactuation pressures through a pressure-sensing diaphragm. This response switches, via a double-pole, double-throw (DPDT) electrical switch assembly, 28 vdc to operate relays located in the vehicle sequencer which, in turn, operates propulsion system solenoid control valves or GSE systems.

- STAINLESS STEEL PRODUCTS

<u>Low-Pressure Ducts, Part Numbers 1A49320 and 1A49969 (Figure 6)</u>

The ducts carry the fuel and oxidizer from the tanks to the engine. A burst or leaking duct would result in liquid hydrogen or oxygen dumping from the system. This would almost certainly result in fire or explosion, and ultimate destruction of the stage, either on the ground or in flight.

- AERVALCO (Division of Snap-Tite, Incorporated) (Formerly Clary)

<u>Propellant Shutoff Valves, Part Number 1A49968 (Figures 2 and 6)</u>

These main propellant shutoff valves are between the propellant tank and the engine. Failure to open would prevent fuel or oxidizer from reaching the main engine. This would either prevent the engine from starting or cause the engine to destroy itself, with resultant loss of the stage.

- AVICA CORPORATION

<u>Bellows, Part Number 1A49986 (Figure 8)</u>

This bellows, in conjunction with a Tee Assembly fabricated by Douglas and consisting of 2 bellows, Aeroquip-Marman Part Number 1A86703-1, is part of the vent system. Rupture of the bellows or leakage in the tee assembly would permit hydrogen gas to escape into the interstage between the S-IVB and the Apollo, creating a fire or explosion hazard. Leak of pressurant gas prior to engine start might preclude start due to lack of sufficient pressure to meet engine inlet conditions. After engine start, the engine operation might be affected, possibly losing the mission or causing the engine to destroy itself.

- CALMEC MANUFACTURING COMPANY (Division of Ametak)

Vent-and-Relief Valves, Part Numbers 1A48257 and 1A48312 (Figure 7)

These valves are used for venting and relieving the LOX and LH_2 tanks. The vent-and-relief valve is a combination valve which enables relief of excess tank pressure in flight or on the ground, or command venting during ground operation or in flight.

If the valve should fail to relieve as the result of tank overpressure, a backup relief valve is provided for redundancy. If the valve should leak, tank pressurization could be lost, and required engine NPSH would not be provided, with a subsequent loss of mission and possible destruction of the engine and stage. On the ground, failure of the valve to respond to command would result in launch schedule delay.

- CALMEC MANUFACTURING COMPANY (Division of Ametak)

Fuel Tank Directional Control Valve, Part Number 1B49988 (Figure 14)

During ground operations, this valve directs all vented gas from the hydrogen tank overboard through the umbilical disconnect for disposal at the facility burn pond. In flight, this valve directs the vented gas out through the stage nonpropulsive vent system. If the directional control valve should malfunction and fail to go from the ground position to the flight position just prior to liftoff, the launch vehicle would be prevented from lifting off through electrical interlocks. An expensive launch preparation would be scrubbed, and the flight rescheduled. Failure of the valve in flight would direct the vented gases from the LH_2 tank through the ground vent propulsively, rather than through the flight nonpropulsive vent system. This propulsive thrust would require additional APS system propellant, and result in premature depletion of propellant with a resultant loss of mission.

3.1.3 LOX Tank Pressurization System

A separate pressurization system is provided for each propellant tank to monitor and control tank pressurization for adequate engine pump net positive suction head (NPSH) during engine start and burn. The LOX tank is pressurized with helium which is stored in submerged bottles in the liquid hydrogen tank. Prior to liftoff, the cold helium bottles are filled through the stage disconnect and check valve system until charged to operating pressure. Pressurization gas from these bottles flows through the LOX tank pressurization control module to the LOX tank during engine operation. On the Saturn V version of the S-IVB stage, where a second engine start is required, a LOX tank repressurization system is also included. High-pressure helium gas at ambient temperature is stored in 4.5-cubic-foot bottles and is used to repressurize the LOX tank prior to second engine start. These bottles are charged on the ground prior to liftoff, along with the pneumatic control sphere and liquid hydrogen tank repressurization bottles. At second engine start, the LOX tank repressurization control module is activated, allowing pressurization gas to flow into the LOX tank.

Failure of these systems to provide the required NPSH for the engine pumps can cause catastrophic failure of the engine and loss of the stage. Failure of the repressurization system prior to second engine start could result in an inability to restart the engine, hence resulting in a mission abort.

A block diagram of the LOX Tank Pressurization system is shown in figure 10.

- VINSON-ADEL INDUSTRIES

Relief Valve, Part Number 7851824 (Figure 4)

This valve is used in the LOX tank repressurization control module to protect the stage against an overpressurization in the repressurization gas storage sphere. Failure of this relief valve to relieve on demand can allow a catastrophic system overpressurization. Leakage through this relief valve to the atmosphere can result in premature pressurization gas depletion.

- AIRTEK (Division of Fansteel Metallurgical Corporation)

Helium Storage Spheres, Part Number 1A49990

These spheres are used to provide gas for repressurization of the LOX tank before the second J-2 engine burn. Since these spheres contain high-pressure gas, they are a potential source of high-energy destructive shrapnel. See figures 9 and 13.

- J. C. CARTER COMPANY

Cold Helium Check Valve, Part Number 1B40824 and Ambient Temperature Helium Check Valve, Part Number 1B51361

Cold helium check valves are used to prevent backflow of cold helium from the LOX tank pressurization storage seals after liftoff. The ambient helium check valves are used to prevent backflow of ambient helium from the LOX tank repressurization system storage spheres. Leakage of helium gas to the atmosphere through these check valves could result in premature loss of tank pressurization supply, and possible mission abort. See figure 4.

CALMEC MANUFACTURING COMPANY (Division of Ametek)

LOX Tank Pressurization Control Module, Part Number 1B42290 (Figure 10)

The LOX Tank Pressurization Control Module contains a filter, a regulator, and solenoid valves for regulation and control of the LOX tank pressure. A closing of either of the filters or valves would prevent proper tank pressurization with resultant loss of stage or mission. The regulator is redundant with an on-off regulator function of one of the solenoid valves. It is believed that a double failure of these regulators is necessary before loss of control would occur. However, should such a loss occur, the stored gas would be prematurely depleted with resultant loss of engine operation. The same malfunction would apply to any external leakage from the module. Improper operation of the solenoid valves would affect either engine performance or the availability of the stored gas to the tank.

Cold Helium Umbilical Disconnect, Part Number 7851844

The Cold Helium Umbilical Disconnect is the ground supply connection to the stage for supplying cold helium to the storage bottles prior to liftoff. Improper separation at liftoff would cause damage to the stage, which could propagate due to aerodynamic forces during flight. This disconnect also provides a shutoff or check-valve function which is redundant with other vehicle check valves. Leakage during flight could cause premature loss of the stored gas. See figure 5.

Cold Helium Fill Module, Part Number 1B57781 (Figure 10)

The Cold Helium Fill Module contains a solenoid-operated dump valve and a relief valve. The dump valve is used to unload the cold helium storage spheres on the ground, and the relief valve provides protection against overpressurization of the storage system on the ground and in flight. The dump valve is used for ground operations only, and is not flight critical, but leakage of stored gas through this valve could result in premature depletion of pressurization gas. Malfunction of the relief valve can be deleterious in two ways: (1) If it should leak, it would deplete the storage spheres and prevent proper operation of the engine, (2) If the relief valve did not relieve when the system was overpressurized, it would force some other component to burst which, by its very nature, is hazardous.

Cold Helium Solenoid Control Valve, Part Number 1B43660

This valve is utilized to control the flow of LOX tank repressurization control helium to the propellant tank prior to second J-2 engine start on the Saturn V version of the S-IVB stage. Failure of these valves to respond on command could result in lack of LOX tank repressurization and an inability to restart the engine, resulting in a mission abort. Helium gas leakage to the atmosphere through one of these valves could result in premature depletion of the repressurization control supply. See figure 4.

- MENASCO MANUFACTURING COMPANY

Cold Helium Storage Spheres, Part Number 1A48858 and LOX Tank Pressurization System Plenum Sphere, Part Number 1A49991

Part No. 1A49991 is used to improve the system pressure regulation characteristics. These spheres are designed to maintain pressure under ambient and liquid hydrogen temperature (minus 423°F). Since they contain high pressure gas, they are a high energy source. The malfunction of this bottle would be extremely serious. If a bottle should burst, it would rupture the main liquid hydrogen tank and be a source of destructive shrapnel. Such a failure could be immediately catastrophic to the vehicle and any personnel in the vicinity, including astronauts. See figure 9.

3.1.4 Pneumatic Control System

The pneumatic control system provides high-pressure helium gas for the operation of the pneumatic-controlled valves throughout the propulsion system. Within the system there are components for the pressurant storage, pressure regulation, and distribution and control. Malfunction of this system would cause a loss of control of the propulsion system components, and could result in either mission loss or complete destruction of the stage through engine or tank blowup.

- STERER ENGINEERING

Actuation Control Modules, Part Number 1B66692 (Figure 12)

These modules are used to control the supply of pneumatic power to the various pneumatically operated valves in the propulsion system. The module consists of two three-way solenoid valves. Failure of either of these solenoid valves to operate would prevent control gas being supplied to the pneumatically operated valve, which would preclude proper system operation and would mean loss of the mission and could mean loss of the stage. Leakage of helium gas through either of these solenoid valves could cause premature depletion of the pneumatic power control supply, and could result in loss of the mission.

- AER-VALCO (CLARY) - Division of Snap-Tite, Incorporated

  Actuation Control Modules, Part Numbers 1B65292 and 1A49982

  These modules are used to control the supply of pneumatic power to the various pneumatically operated valves in the propulsion system. The module consists of two three-way solenoid valves. Failure of either of these solenoid valves to operate would prevent control gas being provided to the pneumatically operated valve, which would preclude proper system operation and would mean loss of the mission, and could mean loss of the stage. Leakage of helium gas through either of these solenoid valves could cause premature depletion of the pneumatic power control supply and could result in loss of the mission. See figure 12.

- VINSON-ADEL INDUSTRIES

  Pneumatic Power Control Module, Part Number 1A58345 (Figure 12)

  This module is used to filter and to regulate helium from the stage storage bottle pressure to the pressure utilized for control of the propulsion system pneumatically operated valves. The module incorporates two filters, two shut-off valves, and a pressure regulator. Failure of the filters to contain contamination could result in component malfunction and subsequent loss of stage pneumatic control. A blocked or collapsed filter would result in a stoppage of gas flow which would cause a loss of mission. Failure of the regulator in the closed position could prevent system operation and would result in loss of the mission. Failure of the regulator to provide pressure within tolerance could result in sluggish valve operation, or could apply high-pressure gas to the downstream system with subsequent component malfunction and possible stage and mission loss. Leakage to the atmosphere through the solenoid valve could cause premature depletion of the pneumatic system gas and result in mission loss. See figure 12.

- PUROLATOR PRODUCTS, INCORPORATED

<u>Helium Fill Disconnect, Part Number 7851823</u>

This disconnect is an umbilical connection where ground supply helium is fed into the vehicle prior to launch. At liftoff, the unit is disconnected. Failure to properly disconnect during liftoff could result in stage structural damage and failure of the internal check valve to seal could cause premature loss of the pneumatic system gas. See figure 5.

- HADLEY ROYAL INDUSTRIES

<u>Engine Pump Purge Control Module, Part Number 1A58547</u>

This module is used to control helium purge flow to the engine pump and to the stage-mounted LOX chilldown pump. Each module consists of an orifice and a solenoid-control shutoff valve. Failure of the solenoid valve to respond on command could result in lack of helium purge gas flow to the stage-mounted LOX chilldown pump or to the J-2 engine pump. Lack of this purge gas could result in failure of pump seals in either of these two systems. See figure 9.

- J. C. CARTER COMPANY

<u>Check Valve, Part Number 1B51361</u>

This is an in-line check valve which is used as a redundant valve to the one mounted in the helium fill module. Backflow through this check valve could cause premature loss of pneumatic system control gas and result in mission loss. See figure 4.

- AIRTEK DIVISION OF FANSTEEL METALLURGICAL CORPORATION

<u>Plenum Sphere, Part Number 1A48857 (Figure 9)</u>

Airtek supplies an in-line plenum sphere which is used to provide a plenum in the pneumatic control system to improve pneumatic power-control-module regulation. Airtek also supplies the helium storage sphere, Part Number 1A49990 (mentioned previously), which is used to store pneumatic power control gas and also to store ambient temperature helium gas for repressurization of the liquid oxygen and liquid hydrogen tanks. Structural failure of these spheres could be catastrophic and result in loss of the stage. Leakage of the helium gas to the atmosphere could result in premature depletion of pneumatic control gas or repressurization gas, and could result in mission loss.

- FAIRCHILD HILLER

Helium Fill Module, Part Number 1A57350

This module consists of a check valve and solenoid valve. The check valve is installed to prevent backflow leakage of the helium gas from the storage spheres to the atmosphere in flight. The solenoid valve provides ground-dump capability. Backflow leakage of the check valve could cause loss of the stored helium and, therefore, make the total system inoperative. Leakage of the overboard dump valve could cause the same loss of system operation.

- W. O. LEONARD

LOX and LH_2 Tank Relief Valves, Part Numbers 1A49590 and 1A49591 (Figure 7)

The relief valve is a redundant backup to the vent and relief valve on each of the propellant tanks to relieve excess tank pressures in flight or on the ground. If the valve failed to relieve when required, the propellant tank would be overpressurized and would rupture destroying the stage. If the valve should leak excessively in flight prior to engine start, the tank pressurant gas would be exhausted to the atmosphere and the engine might not start due to lack of inlet condition. After engine start, engine operation might be affected, possibly losing the mission or causing the engine to destroy itself.

LH_2 Propulsive Vent Regulator Valve, Part Number 1B51753 (Figure 14)

This regulator consists of a solenoid pilot valve, a regulator valve, and a bypass orifice valve. It is used to control the LH_2 tank pressure between predetermined limits, and to control the flow of venting gas from the LH_2 tank to the propulsive vent system in order to maintain sufficient thrust for propellant control during the orbital coast period on the Saturn V version of the S-IVB.

Failure of the regulator or pilot solenoid valve to open on command would prevent sufficient tank venting during orbital coast, and would not allow proper conditioning of propellants prior to second engine burn. The mission would probably be lost due to lack of NPSH during the second burn of the J-2 engine. Excessive leakage through the valve in flight would have the same effect as leakage of the relief valve noted above.

3.1.5 Liquid Oxygen (LOX) and Liquid Hydrogen (LH_2) Tank Fill and Drain, Feed and Vent Systems (Figure 14)

The LOX and LH_2 tank fill systems are designed to minimize prelaunch preparation time compatible with other stages in the launch vehicle. The fill systems are sized to flow 1,000 gpm of liquid oxygen and 3,000 gpm of liquid hydrogen. The propellant tank vent systems are designed to protect the tank structure during all phases of propellant tank loading, stage powered flight, and orbital coast. The propellant feed system supplies propellant from the tank to the engine with a minimum of heat input and pressure loss. A prevalve is provided for emergency shutoff during static firing, and to aid the effectiveness of the engine chilldown system.

Failure of the fill system on the ground would result in launch-schedule delay. Failure in flight would allow propellants to flow from the stage and create a fire hazard as well as premature propellant depletion. Failure of the feed ducts could starve the engine, with possible catastrophic loss of stage and mission.

Failure of the prevalve to respond on command could prevent the flow of propellants to the engine, thereby preventing engine start and resulting in a mission abort.

A schematic of the Saturn V/S-IVB Fuel Tank Pressurization System is shown in figure 15.

- FAIRCHILD/HILLER CORPORATION (Stratos Western)

Fill and Drain Valve, Part Number 1A48240 (Figure 14)

This valve is used for both the hydrogen and oxygen fill systems. This valve is in-line between the liquid umbilical fitting and the main tank. It is the main shutoff valve which prevents overboard loss of the cryogenics in flight. On the ground, if this valve fails to open, it would produce a serious and expensive delay of the launch in flight. If the valve should leak or open, main propellant tanks would dump their fluids overboard with a resultant explosion or fire hazard.

3.1.6 Oxygen-Hydrogen Burner (O_2-H_2)

The O_2H_2 Burner supplies heat to the repressurization gas, namely helium, used in the main propellant tanks. Both of the main tanks must be repressurized just before second engine start. This burner is supplied propellants from the main tanks, and these propellants are burned at a very low mixture-ratio and at a very low pressure. The ignition system for this burner uses a high-voltage spark. This spark is dissipated between an electrode and the face of the injector.

A schematic of the O_2H_2 Burner System is given in figure 16.

- AERVALCO

Propellant Control Valve, Part Number 1B59010 (Figure 22)

These valves are used in the LOX and LH_2 feed systems to the O_2/H_2 burner to stop or start the flow of propellants to the burner. Failure of either of these valves to open on command would prevent ignition of the burner and preclude repressurization of the propellant tanks. Failure to close could present a fire or explosion hazard in the burner. Leakage through these valves could allow LOX or LH_2 vapors to collect in the interstage between the S-IVB and the stage directly below, with an associated fire or explosion hazard.

• GENERAL LAB ASSOCIATES

Burner Ignition System, Part Number 1B59986-501 (Figure 17)

The high-voltage spark which supplies the ignition energy for the O_2H_2 Burner emanates from the engine ignition system. This assembly is composed of a metal box and connected to a cable, all of which is sealed hermetically for space application. The box is mounted to the Stage structure near the O_2H_2 Burner, and the cable is mounted to the burner and terminates near the Propellant injector. There are two of these units per Stage.

Although the O_2H_2 Burner is redundant with a stored gas system, the burner is primary in mission operation. Failure of the burner ignition system to perform forces the missile to call up the stored-gas backup system by use of a malfunction detection circuit in the burner. Even though the redundancy in systems is provided, as mentioned above, mission planning utilizes the two independent systems for pressurization. During preparation over approximately a 10-minute period, prior to second engine start, many malfunctions could occur. These could be as simple as an erroneous reading coming from the Stage, which would later be corrected. Any such malfunction could result in a decision to avoid restart and, therefore, perform one more orbit and attempt restart the next time. If the burner system operates correctly the first time, then the second attempt to go translunar would utilize the backup stored-gas system. It then follows that, if on a first attempt the ignition system fails to light the burner, and, therefore, immediate use of the stored gas-system is called into play, the second translunar attempt is no longer available. This mission flexibility of more than one chance to attempt the translunar portion of the mission is vitally important, because these missions are very, very expensive. The ability to attempt translunar a second time could be valued at many millions of dollars; therefore, it is obvious that very high reliability in the engine ignition system is important to allow mission flexibility.

3.1.7 Auxiliary Propulsion System

The Auxiliary Propulsion System is housed in an independent pod which is hung on the side of the vehicle. There are two (2) per Stage. The function of the Auxiliary Propulsion System is to provide roll control during main engine burn and during the coast period. It provides attitude control for the total vehicle, including the Apollo Capsule. In addition, in the Saturn V Mission, engines in the Auxiliary Propulsion System provide settling for the main propellants, such that only liquids will enter the engine during restart. Malfunctions of the Auxiliary Propulsion System need to be considered in two (2) phases: (1) The Main Engine Burn and (2) The Attitude Control - The Coast Period. During main engine burn, if roll control is lost the vehicle will veer off course and it will be necessary to abort the entire mission. During the coast period, if attitude control is not maintained properly, the vehicle will be pointed improperly for the second burn; therefore, the mission would have to be aborted. During the second coast period after the second burn, attitude control is important because the Apollo modules pull away from the Stage, reverse their direction, and redock with the S-IVB Stage. It must maintain an absolute quiescent attitude.

Summary: Malfunction of the Auxiliary Propulsion System means abortion of the flight. It presents an additional ground hazard because of the hypergolics and high-pressure vessels on board.

- THOMPSON RAMO WOOLDRIDGE (TRW)

Attitude and Roll Control Engines, Part Number 1A39597 (Figure 18)

TRW supplies this engine for the Auxiliary Propulsion System (APS). It is clear from the system description that these engines must function on command to maintain vehicle attitude and roll control. There is redundancy designed into these engines, but sluggish operation or failure of the propellant control valves could cause loss of stage control and the mission.

- SEALOL

Stainless Steel Bellows, Part Number 1A67911 (Figure 19)

Sealol provides these bellows which are assembled by Douglas into the oxidizer and fuel propellant tank assemblies for the Saturn IB version of the S-IVB APS. Two bellows assemblies are utilized in each APS module to contain the required propellants for engine operation in flight. These bellows assemblies are reacted upon by the helium pressurant to expel propellants to the engines as required, irrespective of stage attitude or motion. Failure of these bellows assemblies would result in propellants being unavailable to the engine, with resultant loss of mission.

- VINSON-ADEL INDUSTRIES

Low-Pressure Helium Module, Part Number 1A49998 (Figure 20)

Vinson-Adel Industries supplies this module which provides a means of venting the ullage side of the positive expulsion system on the ground, and a relief function to prevent overpressurization of the low-pressure helium system, in the event of failure of the APS helium pressure regulator. Overboard leakage of helium through this module could result in lack of proper propellant supply to the engines, thereby affecting engine performance, or could result in premature depletion of the pressurization supply and possible loss of the mission.

Quadruple Check Valves, Part Number 1A67912 (Figure 25)

Vinson-Adel also supplies these valves which are installed in the helium pressurization system. These check valves are installed to prevent contact of fuel and oxidizer vapors in the pressurization system. External leakage from one of these check valves would result in premature depletion of the pressurization supply and possible loss of the mission. Internal leakage of the propellant vapors through the check valve into the pressurization system would result in mixing of the hypergolic propellant vapors, with possible catastrophic loss of the stage or mission.

- BELL-AEROSPACE

APS Positive-Expulsion Bladder and Tank Assembly, Part Number 1B39468

Bell-Aerospace supplies this component for the Saturn V version of the S-IVB APS. Two tanks are installed in each APS module to contain the required propellant for engine operation in flight. The internally installed teflon bladder is reacted upon by the helium pressurant to expel propellants to the engine as required, irrespective of stage attitude or motion. An external leakage from this tank assembly would present a fire hazard with possible stage loss; while a failure of the internal bladder would result in propellants being unavailable to the engine, with resultant loss of mission. See figure 21.

- W. O. LEONARD

APS Propellant Control Modules, Part Number 1A49422 (Figure 22)

W. O. Leonard supplies these modules which are installed in series between each propellant tank and the engines. These modules are used for filling, draining, and bleeding the propellant systems on the ground. Malfunction on the ground could cause a schedule slippage due to inability to load propellants, and could cause a fire hazard due to propellant leakage after completion of loading. In flight, a loss of mission could result if a leak developed, or if the module filter element collapsed and impeded the flow of propellant to the engines.

- FAIRCHILD HILLER

APS Helium Pressure Regulator, Part Number 1B54601 (Figure 23)

Fairchild Hiller supplies this regulator which controls the helium pressurant gas used to expel the fuel and oxidizer from their respective tanks, as required, to supply the engines. Failure of this regulator could terminate pressurant supply to the propellant expulsion system and a loss of engine thrust. Failure to regulate pressure within tolerance would result in abnormal pressurant and propellant usage, and could terminate the mission due to premature propellant depletion, premature pressurant depletion, engine failure, or loss of attitude stabilization.

- WESTERN FILTER

Helium Pressurization and Fuel and Oxidizer Propellant Supply Filters, Part Number 1B55934 (Figure 24)

Western Filter provides these in-line filters which are utilized to prevent contamination from entering into the pressurization system and propellant supply system components and thereby cause leakage or component malfunction. Failure of these filters to contain this contamination could result in component malfunction and possible stage loss. External leakage from one of these filters installed in the pressurization system could result in premature depletion of the pressurant gas. External leakage from one of these filters installed in the propellant supply system could present a fire hazard. Filter element collapse could impede the flow of propellants to the engines. Any of these failures could result in loss of stage or mission.

A schematic of the APS is shown in figure 25.

- ELECTRIC COMMUNICATIONS, INC.

Control Relay Package, Part Number 1B57731

Electric Communications supplies the relay control package used to operate engine valve solenoids located in the Auxiliary Propulsion Module. Two relay control packages per vehicle are required, one for each of two modules. Each module contains three 150-pound engines to control pitch, yaw, and roll. Located in the propellant supply lines to each engine are eight solenoid valves, four in the fuel line, four in the oxidizer line. Relays in the relay control package switch power to each set of solenoids, independently, upon command from the I.U.

Two telemetry amplifiers, integral to each package, sense the current through each valve, converting this current load into a proportional voltage. In theory, each valve solenoid draws 1.25 amperes. Therefore, 8 valve solenoids on one monitor circuit indicate 5 volts dc, and 4 valve solenoids on the other monitor circuit indicate 2.5 volts dc. The number of valve solenoids operating can be verified by the monitor circuit voltage output. Both monitor circuits are T/M measurements.

Engines will fail to fire as required, if this package fails.

3.1.7.1 Ullage and Retrorocket Motors

In order to position the propellants in the aft end of the LH_2 and LOX tanks prior to first J-2 engine start, three solid propellant rocket motors are mounted on the aft skirt of the S-IB/S-IVB, and two solid propellant rocket motors are mounted on the aft skirt of the SV/S-IVB.

To provide a deceleration force to the stage below the S-IVB at separation, four solid propellant retrorocket motors are mounted in the interstage between the S-IVB and S-IB stage on the S-IB vehicle, and four solid propellant retrorocket motors are mounted in the interstage between the S-IVB and S-II stage on the Saturn V vehicle.

- THIOKOL CHEMICAL CORPORATION

Thiokol supplies the Ullage Rocket Motor, Part Number 1A81960 (figure 26), and the Retrorocket Motor, Part Number 1A59670 (figure 27). Failure of the retrorockets to ignite on command will affect the separation trajectory and could result in impact between the engine bell of the S-IVB and the stage below, resulting in stage damage and possible mission abort. Failure of the ullage rocket motor to ignite on command could result in propellants not being settled at engine start with a subsequent loss of engine pump inlet conditions and failure of the J-2 engine to ignite. Failure of these motors due to explosion or burnthrough could have catastrophic results and destroy the stage.

3.2 Electrical/Electronic Components

The Electrical/Electronic Components are used throughout the stage in various systems and subsystems to provide distribution and control of electrical power, and signals to operate functional equipment such as valves, motors, and telemetry. For clarification, the electrical system is being divided into the various groups in order to simplify the presentation. These groups will be:

a. Propellant Utilization
b. Power Distribution
c. Switching for Hydraulics
d. Electrical Ignition

In general, the electrical equipment can be broken down into two categories. One category is for operational function of the missile, and the other one is for information, in other words, that equipment which is used to open and close valves throughout the stage, whether for the Propulsion System or the Hydraulic System. These valves, in turn, control propellants, and gases and fluids which, when properly controlled, make the missile perform its mission and, when improperly controlled, can cause malfunction resulting in mission abort or catastrophic failure. For example, a relay in the sequencer which is a very key element of the electrical control system, may cause either mission abort due to improper signal to a valve, or even a catastrophic failure by failing to send a signal to a critical valve. Failure to send a proper sequence of signals for engine cutoff could result in a catastrophic explosion. On the other hand, many electrical components are used for information gathering. Many measurements are made throughout the stage, and this information has to be transmitted either by solid wire or telemetry back to recording systems. Engineers use this information for evaluating performance. In general, instrumentation failures are non-catastrophic, although they can cause mission loss if the mission is an experiment where vital information is available only through the instrumentation system. Redundancy is used in many places throughout the electrical system, but it is not possible to be redundant in every aspect. Therefore, there are single-point failures such as a relay failing to make contact, which can, in fact, result in catastrophic destruction of the stage.

Many space flights have been made in the past, and more, which are unmanned experiments will be made in the future, where the only data available to the experimenter on the ground are provided through the instrumentation system. Proper function of all electrical components in an instrumentation system, from the transducer through to the recorder, are important because these experiments are extremely costly, and cannot be assessed if proper data are not received.

A block diagram of the electrical system is given in figure 28.

3.2.1 Propellant Utilization System

The first subsystem to be considered will be the Propellant Utilization System (PU). The primary function of this system is to detect mass of propellant in each tank, and to supply that information to an electronic package which, in turn, controls an engine valve in order to properly utilize all of the propellants on board the Stage. This system also supplies a signal to a ground loading computer in order to accurately load the desired propellant masses into the Stage. Overall Stage performance capability is intimately linked with complete use of all the propellant on board. Malfunction of the propellant utilization system, such as supplying an erroneous signal to the engine mixture ratio valve causing it to go hard-over, could cause mission loss because lack of performance of the Stage to accomplish the orbit designated would result. Also, it is possible to abort a mission on Saturn V by improperly controlling the engine mixture ratio valve during a preprogrammed portion of the first burn, resulting in improper charging of the engine start bottle, therefore making it impossible to accomplish a second start. A second engine start is necessary to go translunar.

The Propellant Utilization System is primarily made up of three (3) major elements:

a. The Capacitance Probes (figures 29 and 31) which are located inside the propellant tanks
b. PU Electronics Assembly (figure 30)
c. Engine Mixture Ratio Valve Positioner

- AMERICAN ELECTRONICS

Motor Transmission, Serval Bridge, Part Number 1A59320

This component (figure 30) is located in the Propellant Utilization Electronics Assembly, and its purpose is to position a 4-section potentiometer. The motor receives a drive signal from the bridge amplifier and, in response to this signal, positions the 4-section potentiometer for the Propellant Utilization System. Should this motor fail to accomplish its assigned task when commanded, the result would be a loss of mission. In general, astronaut safety is not directly involved, because the mission is planned to allow for astronaut escape and safe return in the event of mission loss. It should be said that failure of this component effects the end of flight and, therefore, astronaut safe return to earth is more risky than if it occurred earlier in the flight.

- MAGNETIKA

LH_2 Bridge Transformer, Part Number 1A59568 (figure 30)
LOX Bridge Transformer, Part Number 1A59569 (figure 30)

These transformers are used as two legs of the electrical bridging network within the Propellant Utilization Electronics Assembly. Should one or both of these transformers fail to accomplish their design requirement, the net result will be loss of the mission. Astronaut safety is not directly involved in a mission loss, because the program plan calls for safe return of the astronauts to the earth in the event of a mission loss which is noncatastrophic. A failure, or failures, in these transformers is felt by the missile at the end of its powered flight. Therefore, it should be noted that astronaut safe return to the earth is more risky than if the failure occurred earlier in flight.

- INTERNATIONAL RESISTOR CORPORATION

Resistor, Variable Multiturn, Wire Wound, Part Number 1A59563

These resistors (figure 30) are used as voltage rheostats and calibration adjustment potentiometers. A failure of one of these resistors during checkout will result in considerable additional work to be accomplished on the Stage. Failure of one of these resistors during the launch operation could result in scrubbing a test and, therefore, a waste of considerable money. A failure of one of these resistors during flight would probably result in a loss of mission. Astronaut safety is not directly related to a noncatastrophic loss of mission. The program plan requires safe return to the earth of the astronauts throughout the mission. Should a failure of one of these resistors occur in flight, the effect would be felt by the Stage at the end of a powered operation. Safe return of the astronauts to the earth late in the mission is more risky than early in the mission.

- LITTON PRECISION PRODUCTS

Potentiometer, Bridge, Propellant Utilization

This 4-section potentiometer (figure 30) provides electrical feedback for the circuit, gives bridge readout for the T/M System, and provides signals for the engine valve circuits. Failure of this component to function as required will result in improper control of the engine mixture ratio valve. Result of this improper control can be the incorrect use of propellants during powered flight. If the failure of this component occurs during a particular time period of powered flight, the net result could be a mission loss. Astronaut safety is not directly related, because the mission plan allows for safe return of the astronauts to earth in the event of a non-catastrophic mission loss. It should be noted that the mission criticality of failure in this component is late in the trajectory, namely translunar, and astronaut return and safety are more complicated and risky.

- HONEYWELL

The Oxidizer Mass Probe, Part Number 1A48430
The Fuel Mass Probe, Part Number 1A48431

The LOX and LH_2 Mass Probe (figure 29) are cylindrical capacitors and are mounted inside the main propellant tanks. When submerged in the liquids of their respective tanks, they provide a variation in capacitance linearly with the mass of the propellants in those tanks. This variable capacitance, as effected by the mass of propellant in the main tank, is the input to the propellant utilization electronic assembly which, in turn, programs to the engine the requirements of the mission for properly utilizing the propellant remaining on board. Improper output from the capacitance probes, or lack of output, can result in mission loss. For example, in the Saturn V Mission, specifically the manned flight to the moon, these mass probes are vital because, without proper propellant utilization, inadequate stage performance will result. Proper control of mass probe during first burn is necessary, in order to recharge the engine start bottle in preparation for a second engine start.

In summary, accurate and safe loading of propellant while on the ground, proper control of engine mixture ratio to accomplish necessary engine conditions required for second start, and efficient use of propellant during engine operation are vital requirements of the S-IVB Stage. The mass probes are a very important element in a system required to accomplish the above requirement.

- SIGNET SCIENTIFIC

Oven, Component, Propellant Utilization, Part Number 1A59564

This oven (figure 30) provides a stable temperature environment for the Propellant Utilization System Reference Capacitors. The calibration of the total propellant utilization system is dependent on stable temperature control for the reference capacitors. Once calibrated, this system must always operate at the same reference temperature conditions to stay within the original calibration. Improper operation of this oven during a launch operation could result in a launch abort. This is an extremely costly launch operation and, therefore, considerable money is involved in launch delays. Failure of this oven to provide stable temperature environment during flight, especially on Saturn V, will undoubtedly result in loss of mission. Astronaut safety is not directly involved with a noncatastrophic mission loss. The failure in this oven is felt by the missile at the end of powered flight. Safe astronaut return to the earth is a part of the mission plan. But higher risk is involved near the end of the mission for the S-IVB than if such failures occurred earlier in the mission.

- SAN FERNANDO ELECTRIC

Capacitor, Motor Tuning

This capacitor (figure 30) changes the power factor of the reference voltage phase of the engine valve motor. Improper operation and response of the engine valve motor, as influenced by this capacitor, can result in mission loss. This mission loss is caused by inefficient use of propellants during power operation, therefore, resulting in effectively running out of gas. Astronaut safety is not directly involved, because the program plan calls for safe return to earth of the astronauts during any phase of the trip to the moon. A failure of this capacitor is effectively felt by the stage late in the flight; therefore, it should be noted that astronaut return, safe return, to earth is slightly more risky than if the failure occurred earlier.

3.2.2 Power Distribution

The power distribution system of the Stage is made up of numerous assemblies, and these assemblies, in turn are made up of various components, both electrical and electronic. This system distributes and controls all electrical power to the Stage, whether it originates from the ground or from the on-board batteries. Each specific component noted on the agenda cannot be covered; therefore, typical examples will be used. For example, a relay may be used in numerous subassemblies. One example for each Vendor's product will be used to show a typical use, and will show an end result if a malfunction of his product should occur.

The Forward Control Distribution Assembly is identified on figure 31).

The Aft Control Distribution Assembly is shown in figure 32).

- BENDIX

Semiconductor Device-Diode Power, Part Number 1B54541

These diodes (figure 33) are used for electrical isolation in various modules and systems throughout the vehicle. A failure of a diode can subject the vehicle to improper influences from spurious signals. It is possible for this situation to reach serious proportions and, therefore, result in loss of mission. Astronauts safety is not directly related to a noncatastrophic loss of mission. There are always risks in any abnormal mission and, therefore, aborting in flight is undesirable. The program plan calls for the ability to safely return astronauts to the earth throughout the mission. But it should be noted that failures late in the mission represent greater risk to the astronauts than failures early in the mission. Diode failure can occur any time throughout the mission and, therefore, could abort a mission late in its sequence.

- KINETICS CO.

300-Ampere Power Transfer Switch, Motor Driven, Part Number 1A68085

This switch (figure 34) is used to transfer from ground power to on-board battery power. In the event of failure of this switch while on the ground, when a command is given to transfer from on ground to internal power the countdown would have to be aborted. This results in an unnecessary expenditure of money, and, in general, the operation is not likely to be disastrous. In the event of a failure of this switch in flight due to any cause, such as vibration, the entire mission would be aborted. It is possible under certain circumstances that a failure of this switch would result in catastrophic destruction of the Stage. The same general comments above apply to the 50-Ampere Hour Motor Driven Switch, Part Number 1A88061.

- PLANAUTICS

Motor Driven Switch, 50-ampere, Part Number 1A88061

This switch (figure 33) is used to transfer from ground power to on-board battery power. In the event of failure of this switch while on the ground, when a command is given to transfer from on ground to internal power the countdown would have to be aborted. This results in an unnecessary expenditure of money and, in general, the operation is not likely to be disastrous. In the event of a failure of this switch in flight due to any cause, such as vibration, the entire mission would be aborted. It is possible under certain circumstances that a failure of this switch would result in catastrophic destruction to the Stage. The same general comments above apply to the 50-Ampere Hour Motor Driven Switch, Part Number 1A88061.

- BABCOCK

General Purpose Relay, Part Number 1A67747

These relays are used in modules throughout the sequencer (figure 35) which, in a sense, is the heart of the electrical power distribution system. The sequencer operation must be proper in order for the Stage to accomplish its mission. There are both mission abort failure modes and catastrophic failure modes that could exist as a result of this relay failure. This includes Static Firing, where improper commands could result in expensive test aborts or catastrophic failures. Lack of electrical contact on relays in switching can be very serious problems.

Magnetic Latch Relay, Part Number 1B42260
General Purpose Relay, Part Number 1B58584
Magnetic Latch Relay, Part Number 1B58777

A block diagram of the S-IVB Stage sequencing system is shown in figure 35).

The S-IVB sequencing mounting assembly with relay and diode modules is shown in figure 36). The sequencing panel is shown in figure 37.

* GENERAL ELECTRIC COMPANY

<u>Crystal Can Relay, Part Number 1B39033</u>
<u>General Purpose Relay, Part Number 1B50992</u>

These relays are used in modules throughout the sequencer, which, in a sense, is the heart of the electrical power distribution system. The sequencer operation must be proper in order for the Stage to accomplish its mission. There are both mission abort failure modes and catastrophic failure modes that could exist as a result of this failure relay. This includes Static Firing, where improper commands could result in expensive test aborts or catastrophic failures. Lack of electrical contact on relays in switching can cause very serious problems.

* POTTER BRUMFIELD

<u>General Purpose Relay, Part Number 1B52237</u>

These relays are used in modules throughout the sequencer, which, in a sense, is the heart of the electrical power distribution system. The sequencer operation must be proper in order for the Stage to accomplish its mission. There are both mission abort failure modes, and catastrophic failure modes that could exist as a result of this failure relay. This includes Static Firing, where improper commands could result in expensive test aborts or catastrophic failures. Lack of electrical contact on relays in switching can cause very serious problems.

3.2.3 <u>Hydraulic - Electrical</u>

* MASON ELECTRIC CO.

<u>Switch, Motor Starter, Part Number 1B32647 (Figure 38)</u>

This switch is used in the hydraulic system. Its function is to control starting and running current for the auxiliary hydraulic pump. This pump is driven by an electric motor which draws very high current while starting. This pump satisfies many functions as follows:

a. It supplies pressure for ground checkout of the hydraulic system (main hydraulic pump is driven by the LOX pump turbine of the J-2 rocket engine).

b. It supplies pressure prior to J-2 engine start in flight, and it supplies recirculation of hydraulic oil during orbital coast to prevent freezing of this oil due to very low temperatures.

A failure of this switch can cause an aborted test or launch, and can cause catastrophic failure in flight. For example, if the hydraulic oil became frozen solid due to lack of recirculation, the vehicle would probably break up after engine restart because lack of steering could overstress the structure.

3.2.4 Electrical Ignition

• EAGLE-PITCHER

Battery, Wet - Forward and Aft No. 1 Bus, Part Number 1A59471 (Typical)
Other Part Numbers, 1A68316, 1A68317, 1A83468, 1A83469, 1A83470, 1A93471

The batteries are utilized to provide the primary electrical power to the S-IVB stage. There are presently four battery systems on the stage to perform the following functions:

a. Forward No. 1 battery (figure 39) (28 VDC) provides power to the telemetry equipment, switch selector, and propellant dispersal system No. 1.

b. Foward No. 2 battery (28 VDC) provides power to the propellant utilization electronic assembly, the propellant utilization static inverter, and propellant dispersal system No. 2.

c. Aft No. 1 battery (28 VDC) provides power for the J-2 engine, sequencer, pressure switches, and all propulsion valves.

d. Aft No. 2 battery (56 VDC) provides power to the LH_2 and LOX chilldown inverters and the auxiliary hydraulic pump motor.

Due to the fact that the batteries provide the primary mode of electrical power, the loss of any stage battery during the mission would result in mission loss and/or mission abort. Mission loss or mission abort is undesirable from an astronaut safety or recovery standpoint.

A typical S-IVB Stage battery is shown on figure 40 .

3.3 Structural/Mechanical System

3.3.1 Hydraulic System

The hydraulic system is used for gimbaling the main engine to provide directional control during main engine burn. There are two (2) sources of hydraulic pressure. One is from the main engine-driven pump and the other is from an electrically driven pump. These feed pressure to an accumulator which stores energy, and feed two actuators that gimbal the main engine at right angles.

Summary: Malfunction of this system would cause loss of mission by improper direction of the vehicle.

- VICKERS

Main Engine-Driven Pump, Part Number 1A66240 and Auxiliary Hydraulic Pump, Part Number 1A66241 (Figure 41)

Vickers supplies these pumps which redundantly supply the hydraulic pressure to operate the system. Functioning of the auxiliary driven pump, in addition to the auxiliary hydraulic pump, provides ground source for pressure. This pump holds the pressure before the main engine is ignited. Furthermore, this pump provides thermal conditioning for the oil during ground operation and coast. Failure of this pump could cause a delay or interruption of the launch. If the pump failed during flight, the oil could reach an unusable cold temperature, and thereby make the total hydraulic system inoperative. In its redundant function, its loss is less critical, but it provides for an inoperative or malfunctioning main engine pump and slow leakage from the accumulator. Main engine pump provides high pressure and high flow capacity necessary for the specification rates of engine movement. Loss of the main engine pump would most certainly mean loss of mission. Under high gimbaling rates of the main engine, the auxiliary hydraulic pump would be unable to keep up with the demand. The main pump, therefore, is critical under these circumstances where high maneuvering rates are required. The main engine pump is essential; its loss would prevent the required maneuvering and, therefore, loss of mission.

• BERTEA PRODUCTS

Accumulator Reservoir, Part Number 1B29319 (Figure 41)

Bertea Products supplies this vessel which stores hydraulic pressure under high pressure to provide for the surges that the pumps would not normally accommodate. Not only is the pressure used to supply the actuators, but it also provides a higher back-pressure for the pumps to work against. Malfunction of the accumulator reservoir would result in loss of attitude control for the total vehicle. There are many modes of failure that would give this result.

3.3.2 Ordnance Systems

Several ordnance systems are used aboard the S-IVB stage to accomplish vital functions. Among these are the separation of the stages, the ignition systems for solid-propellant rocket motors, a rocket jettison system, and a system to cause destruction of the stage in case of vehicle malfunction. All of the systems on the Saturn V S-IVB stage are initiated by means of electric detonators of the exploding-bridgewire type. An electric firing pulse is delivered to each detonator from an electronic firing unit. Explosive fuse assemblies then carry the detonation to the device being actuated--such as the separation fuse which then detonates, or to the initiators which in turn cause the rocket motors to burn.

The very presence of explosives represents some degree of hazard to (1) the technicians effecting the installations, (2) the very costly vehicle itself, and (3) the astronauts aboard. Extensive measures have been taken during the design phase to insure that the resulting systems have the highest degree of safety, yet accomplish the explosive function when properly commanded.

The S-IVB Ordnance Systems consist of S-IVB ullage rocket ignition, S-II/S-IVB separation system, S-II retrorocket ignition, S-IVB ullage rocket jettison, and the propellant dispersion system. The first four of these systems are required for staging. The fifth system is a requirement of the test range. Failure of the ullage rocket ignition system or the separation system would cause loss of the mission. Failure of the ullage rocket jettison system would reduce the mission capabilities.

The EBW detonator is manufactured by McCormick Selph. The S&A Device is manufactured by Douglas and utilizes a rotary solenoid manufactured by Ledex, Inc. Ullage rocket motors and retrorocket motors are manufactured by Thiokol Chemical Corporation. The EBW motor initiator is manufactured by Aerojet-General. The rocket pyrogen initiators are manufactured by Link Ordnance. The confined detonating fuse is manufactured by Ensign-Bickford. The CDF manifolds are manufactured by Explosive Technology, and the confined detonating fuse assemblies are made by Douglas. Failures of any of these components can cause the system failures noted above.

- ENSIGN-BICKFORD COMPANY

Confined Detonating Fuse Assembly, Part Number 1B53581 (Figure 42)

Confined detonating fuse assemblies are used in the train of explosives between the ignition source (detonators) and the explosive devices to be functioned (destructors and rocket motor initiators). The fuse assembly consists of a small lead-covered explosive charge running the entire length of the assembly, the ends of which are equipped with machined connectors. The column of explosive is encased in a multilayer fabric covering which is capable of completely confining all the products of detonation. Fuse assemblies are routed in a manner similar to electrical cabling, are secured in suitable clamps, and are as long as required to run from the detonators to the device being functioned.

Although the possibility is remote that failures would occur in two fuse assemblies used as pairs within the same system, a failure mode caused by improper assembly of the booster charge to the lead-covered fuse, resulting in a poor explosive interface, could result in multiple fuse failures, hence, system failures. Failure of the fuses to function in the retro-rocket ignition system would result in failure to accomplish proper staging, hence, loss of the entire mission. Failure of the fuses to function within the destruct system might result in a stage, loaded with propellants, impacting in an inhabited area, with resultant loss of life.

- MC CORMICK-SELPH ASSOCIATES

Exploding Bridgewire Detonator, Part Number 7865742-1 (Figure 42)

The EBW detonator, used to initiate all of the ordnance functions on the S-IVB stage, functions on the exploding-bridgewire principle, where a high voltage, high energy pulse from a mating power supply causes a small bridgewire within the device to explode, thereby releasing adequate energy to initiate the adjacent explosive charge. The unit is extremely safe and cannot be inadvertently initiated by normal ground power or stage power. Additionally, a spark gap within the detonator electrical circuit precludes accidental dudding of the device.

To obtain the degree of system reliability required, all the ordnance systems employ two sets of detonators and two firing units. However, in spite of these design precautions, system failures are possible. A premature firing of a detonator could result in a major disaster. This is particularly critical both during prelaunch and flight operations because of the nature of the systems which could be initiated. For example, actuation of the destruct system could destroy the launch complex, the vehicle, and the personnel. Additionally, a premature stage separation or rocket ignition would result in total vehicle-and-mission loss.

A failure of a detonator to fire is also a critical malfunction. The ultimate reliability goals required for Saturn program success cannot be achieved through redundant design only. It is necessary for each detonator to fire upon command, achieve the proper staging sequence in flight, and to protect the crew members and ground personnel.

In the event that it is necessary to destruct the stage after liftoff, the detonators must function upon command to prevent major damage and loss of life in nearby populated areas.

* EXPLOSIVE TECHNOLOGY, INC.

Confined Detonating Fuse Tee Assy, Part Number 1B53585 (Figure 42)

The destruct system on the S-IVB stage utilizes an explosive tee assembly, for use in conjunction with confined detonating fuse assemblies. The tee is a small machined block containing an explosive charge and three threaded ports. Tee assemblies are used to permit attachment of a branch explosive train. As used in the destruct system, the tee assembly permits a branch fuse assembly to extend between the parallel fuses which are connected to the destruct charges. The tee assemblies are vital to proper system functioning, because they cause simultaneous functioning of the destructors.

Failure of the tee assembly to do this function, because of improper manufacture, would mean loss of one of the two destructors. Failure of both the tee assemblies, if destruct action were required, would prevent the destructors from firing, and permit a stage loaded with propellant to impact, possibly in an inhabited area, with resultant loss of life.

3.3.3 Hydraulics

* UNITED CONTROLS

Thermal Switch, Part Number 1A74765 (Figures 41 and 43)

This switch is used in the hydraulic system. The hydraulic system provides forces to the engine for gimbaling as required to steer the missile. The requirement of the switch is to command "on" and "off" an electric driven auxiliary hydraulic pump as a function of system temperatures. Very low temperatures can be experienced while on the ground or while in space; therefore, it is necessary to recirculate the hydraulic fluid in order to prevent freezing of this fluid.

Failure of this switch in flight can cause mission abort or catastrophic failure. Failure of this switch on the ground will cause scrubbing of an expensive test operation. An example of failure of this switch in flight would be to cause freezing of the hydraulic fluid, resulting in improper maneuvering and possible breakup of the missile after engine restart.

- MOOG, INC.

Main Actuators (Figure 41)

Moog, Inc., supplies the two main actuators that move the engine on command. These are installed at right angles to provide pitch and yaw control for the main engine. Failure of the actuators to function properly will cause the vehicle to veer off its controlled flight path, requiring a mission abort. A lesser failure, leakage in the actuators, could cause loss of hydraulic fluid such that the time the engine would be under control would be limited.

- PNEUDRAULICS

High-Pressure Relief Valve (Figure 41)

Pneudraulics supplies this relief valve which is applied to the accumulator and protects against either of the two pumps providing over or excessive pressure. Failure of this valve in the open condition would cause loss of hydraulic pressure, and thereby make the whole system inoperative.

- PARKER

Check Valve

Parker supplies one flight critical check valve for the system. This check valve isolates the main engine pump from the auxiliary hydraulic pump such that a failure in the reverse direction of this check valve would cause the auxiliary hydraulic pump to windmill the main engine pump instead of supplying the accumulator.

The S-IVB hydraulic system and electrical control system are shown in figure

Hydraulic component locations are given in figure 41.

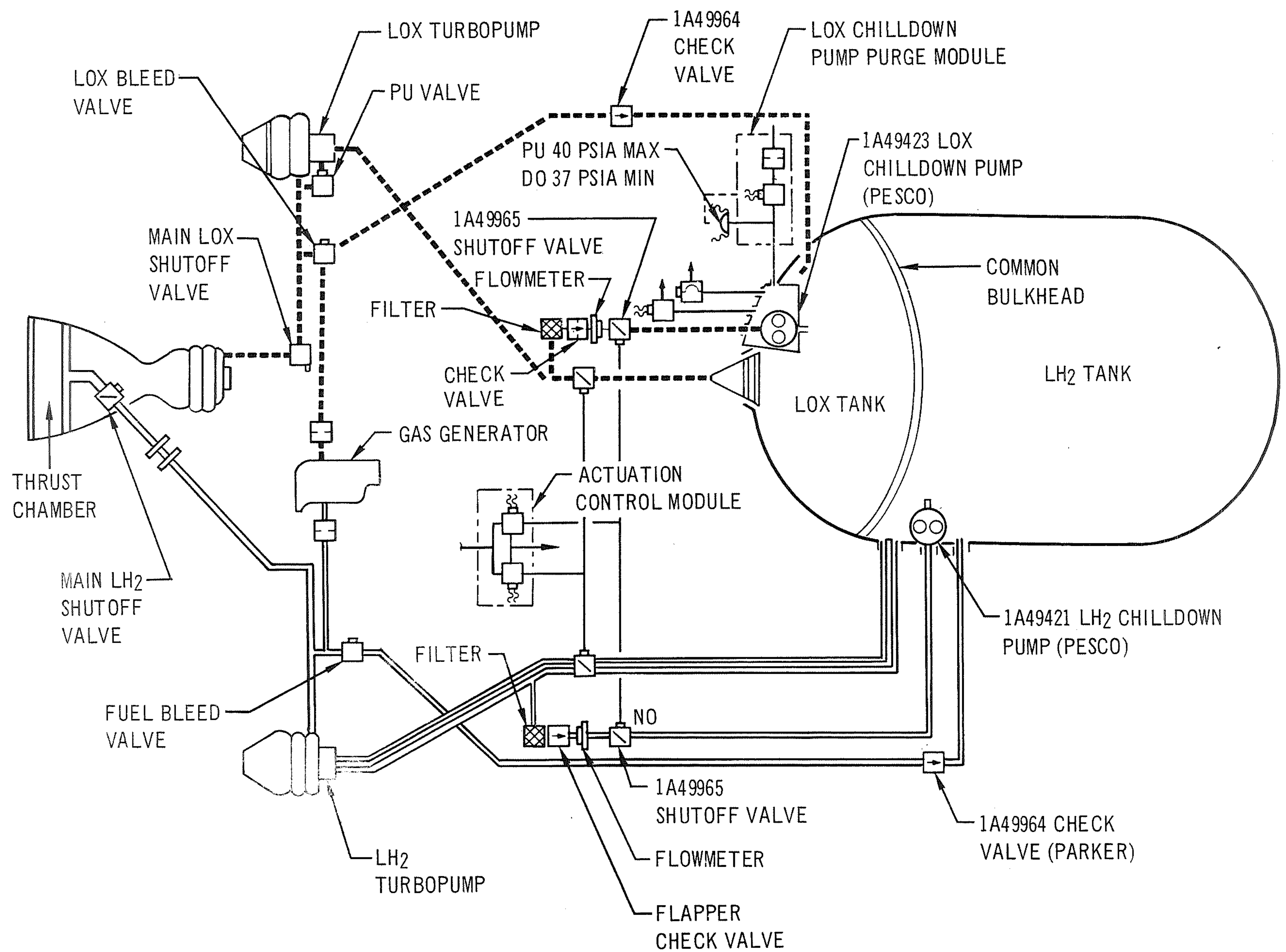


Figure 1. Chilldown System (Sheet 1 of 2)

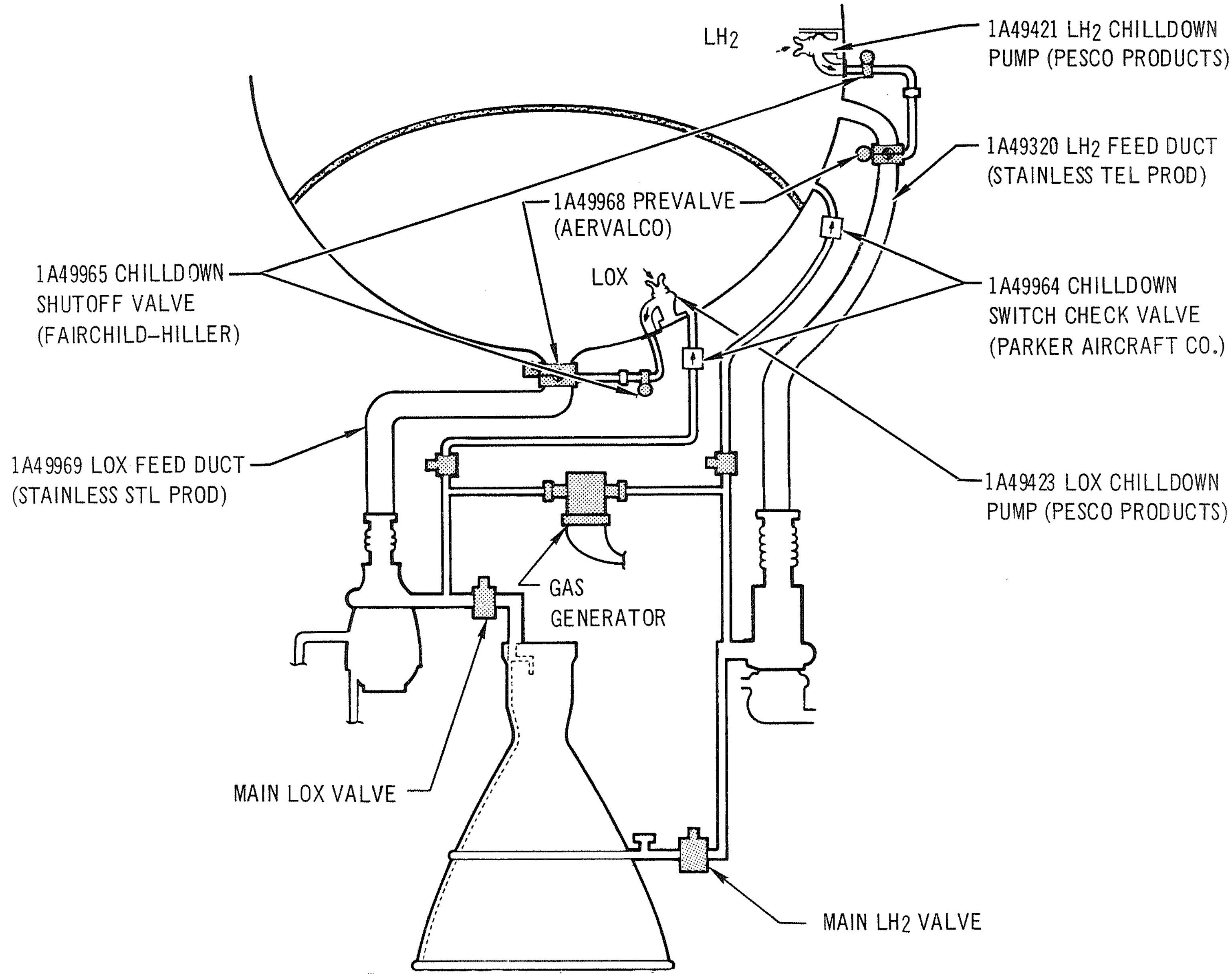


Figure 1. Chilldown System (Sheet 2 of 2)

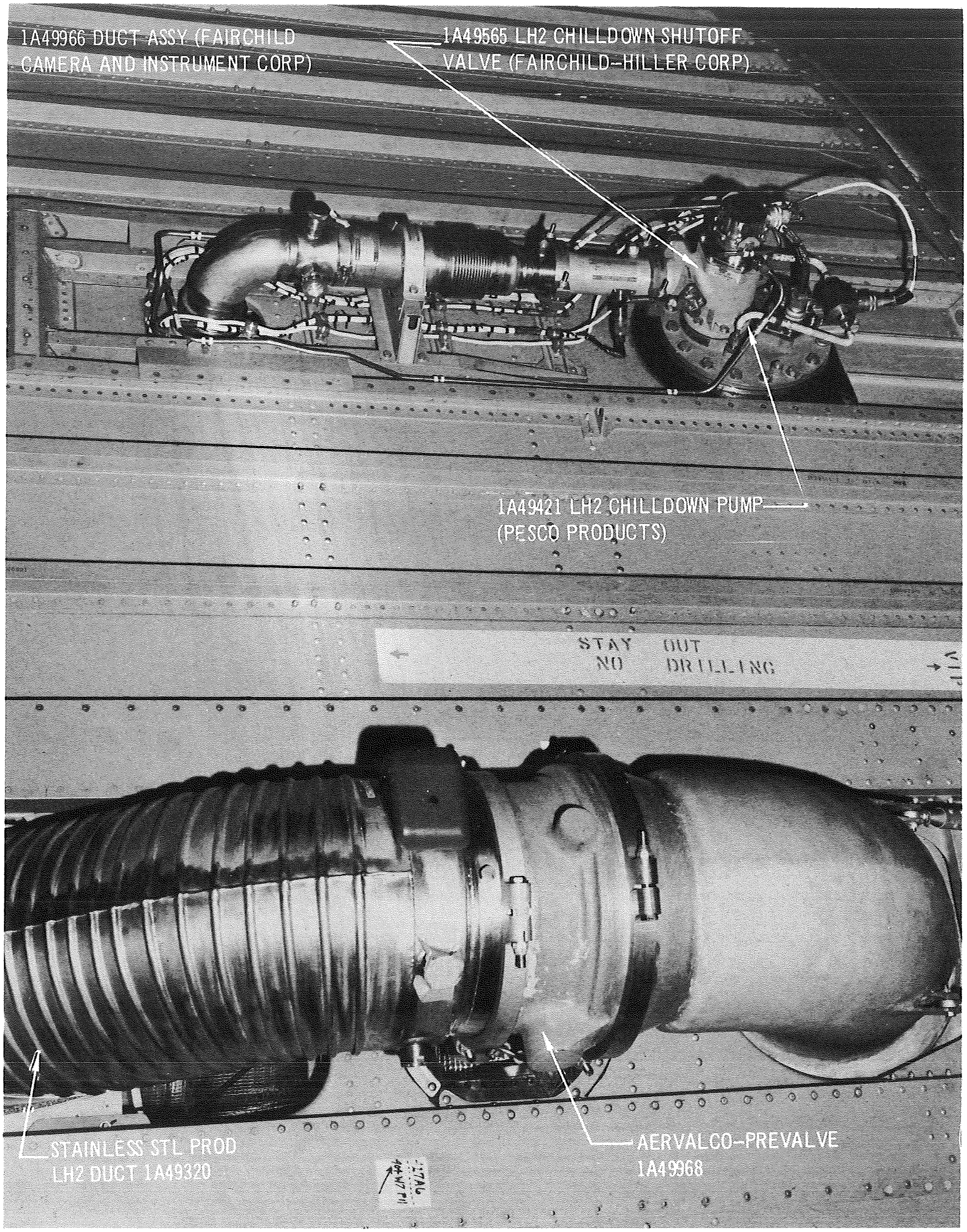


Figure 2. Chilldown Recirculation System Components

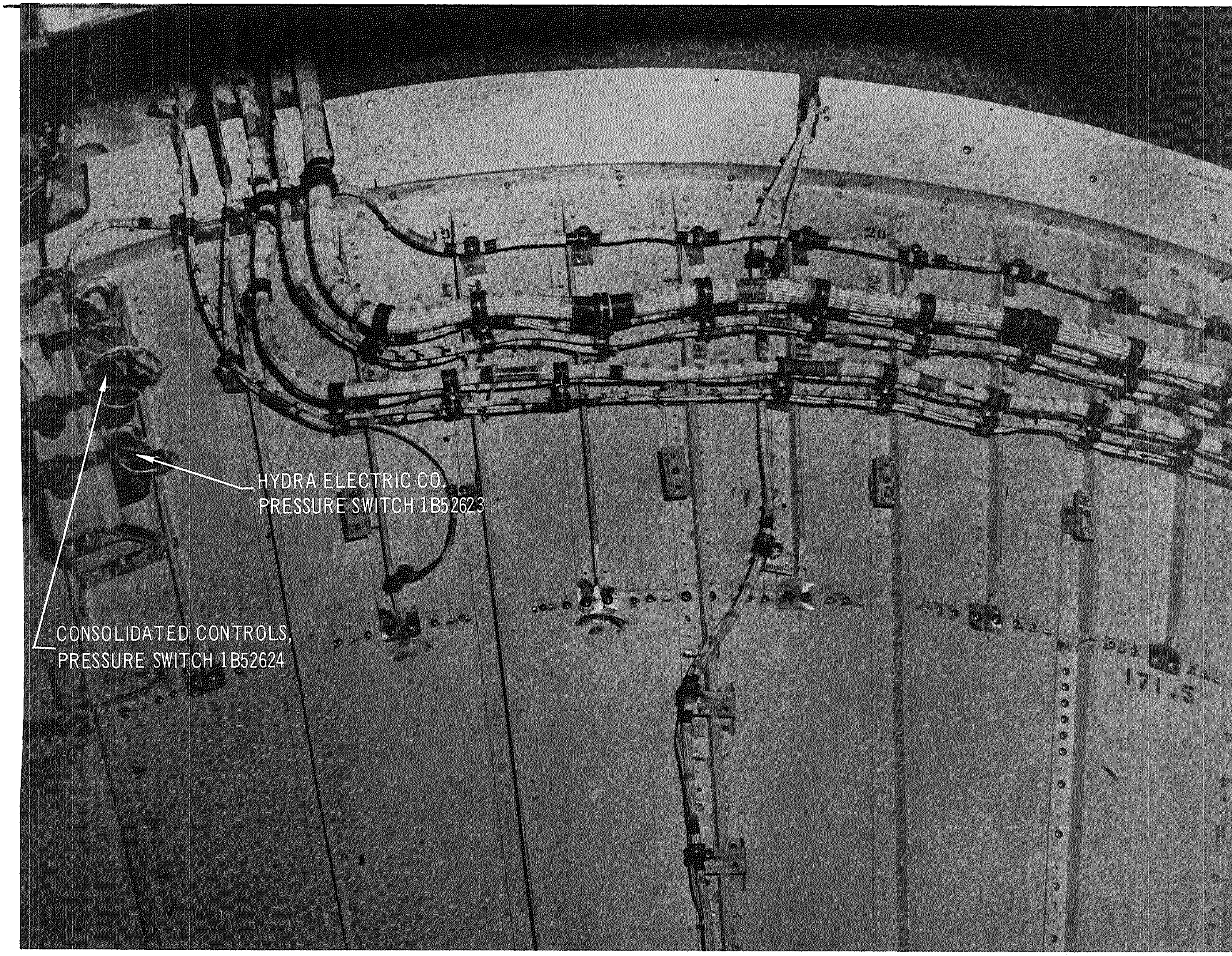


Figure 3. Pressure Switches (Sheet 1 of 2)

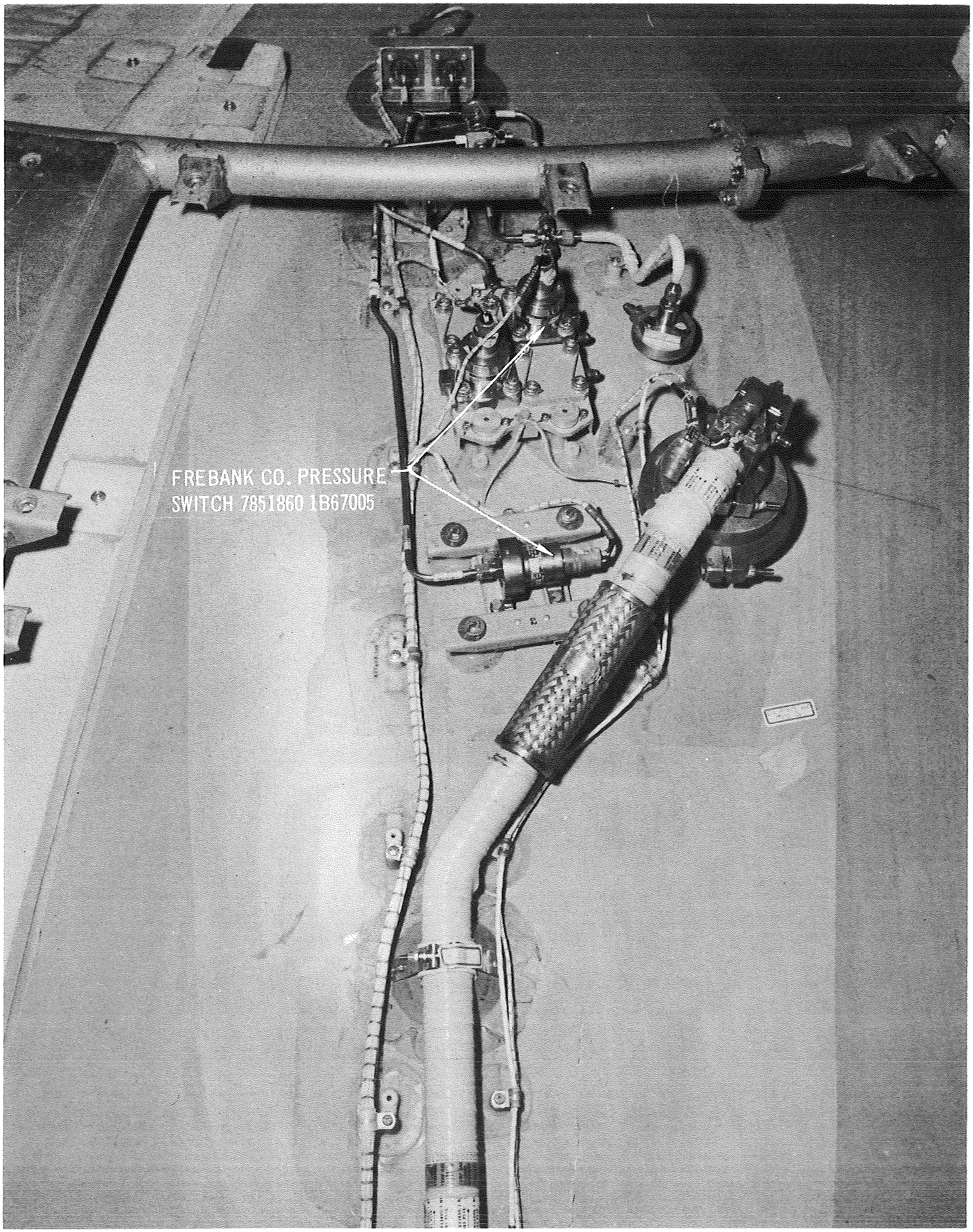


Figure 3. Pressure Switches (Sheet 2 of 2)

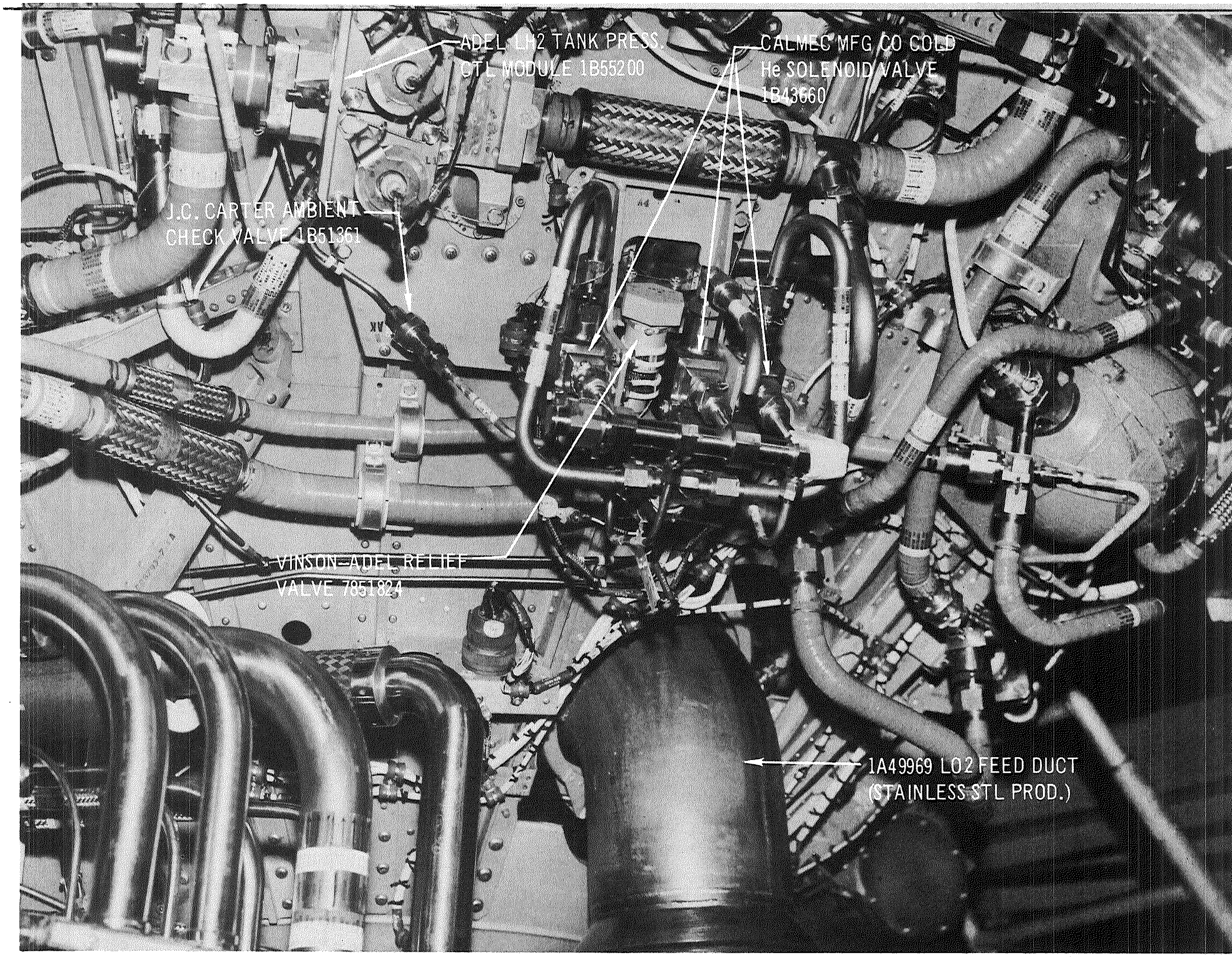


Figure 4. Propulsion System Components

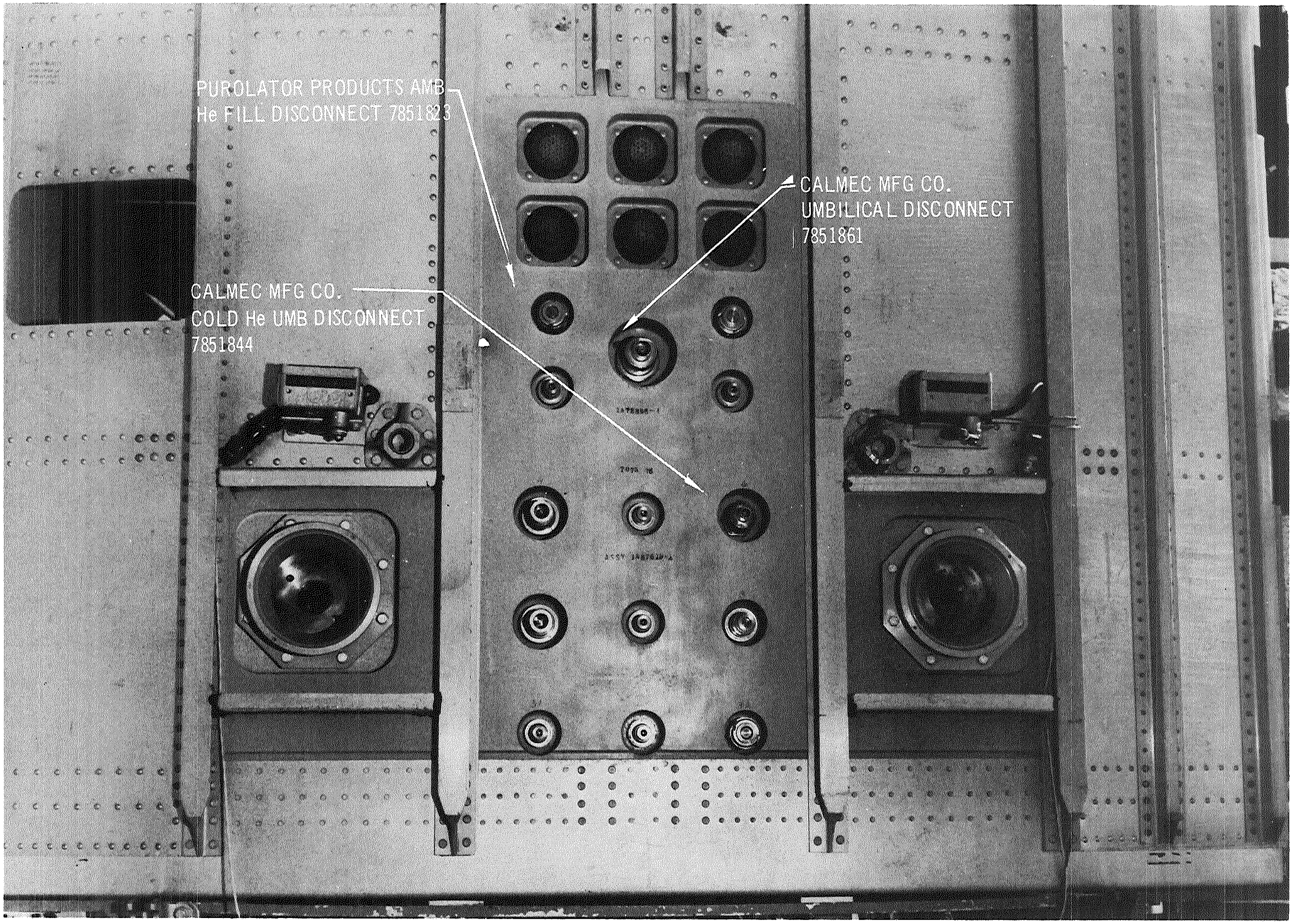


Figure 5. Pressurization System Disconnects

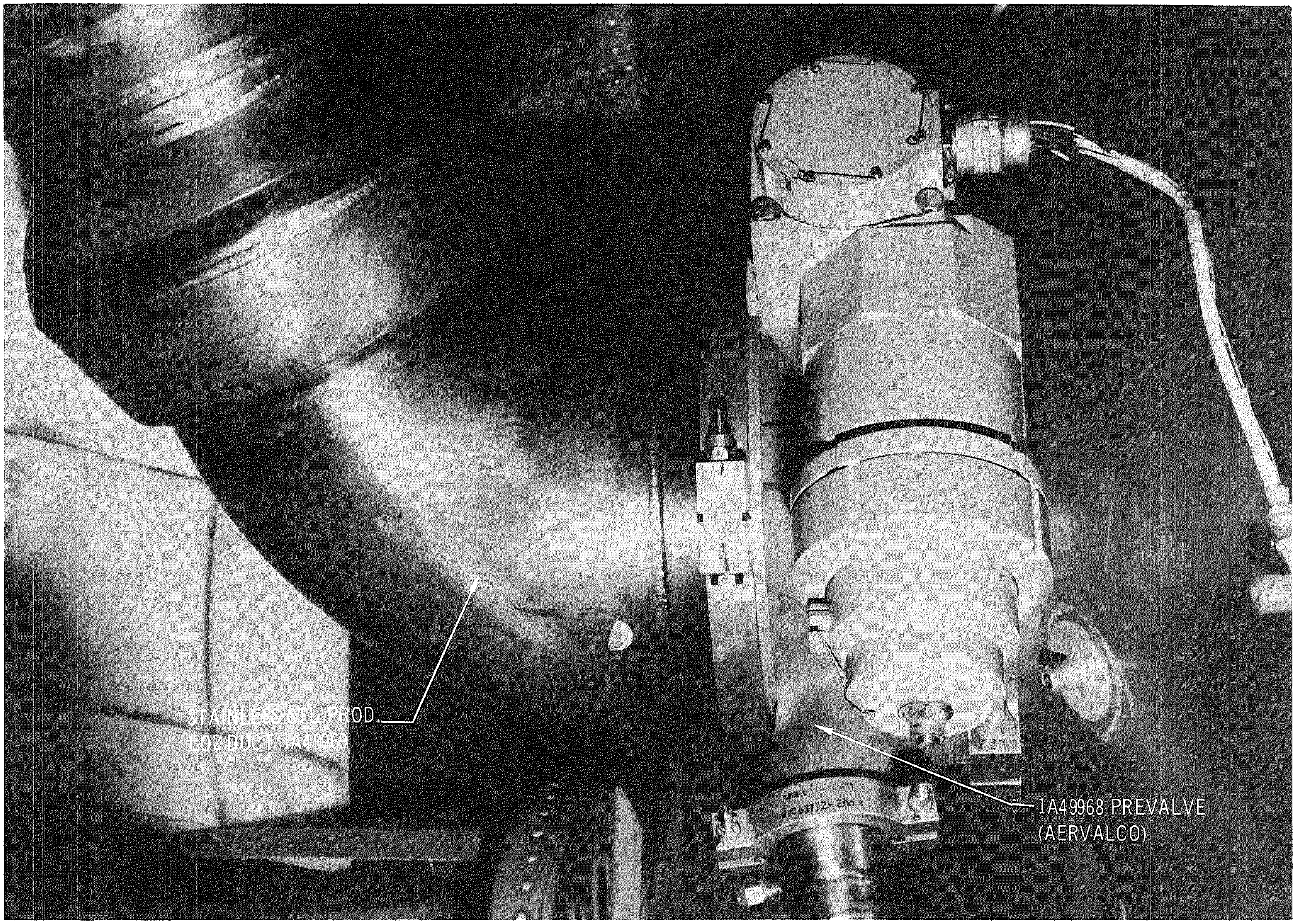


Figure 6. LO2 Duct and Propellant Shutoff Valve

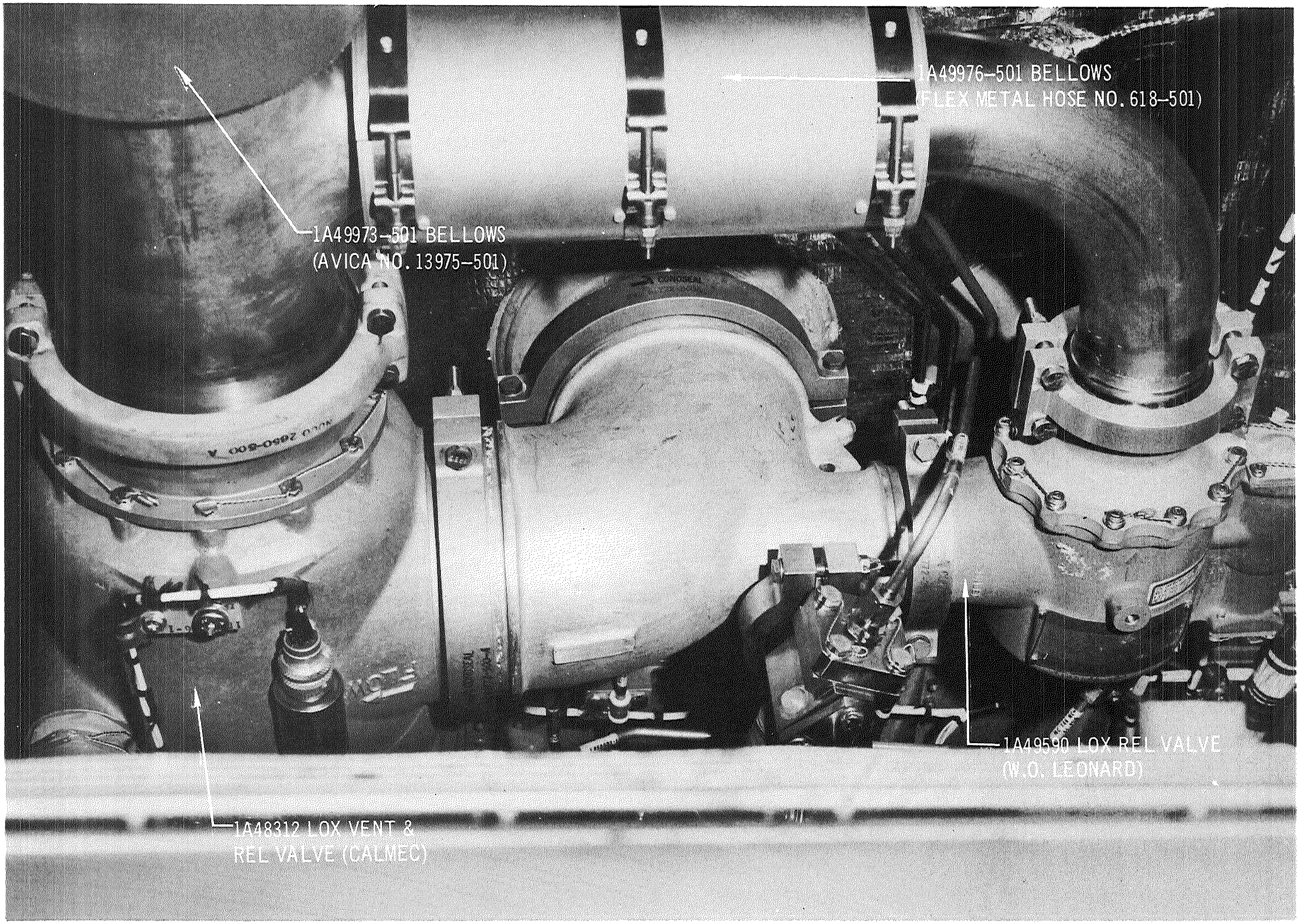


Figure 7. LOX and LH2 Vent and Relief System

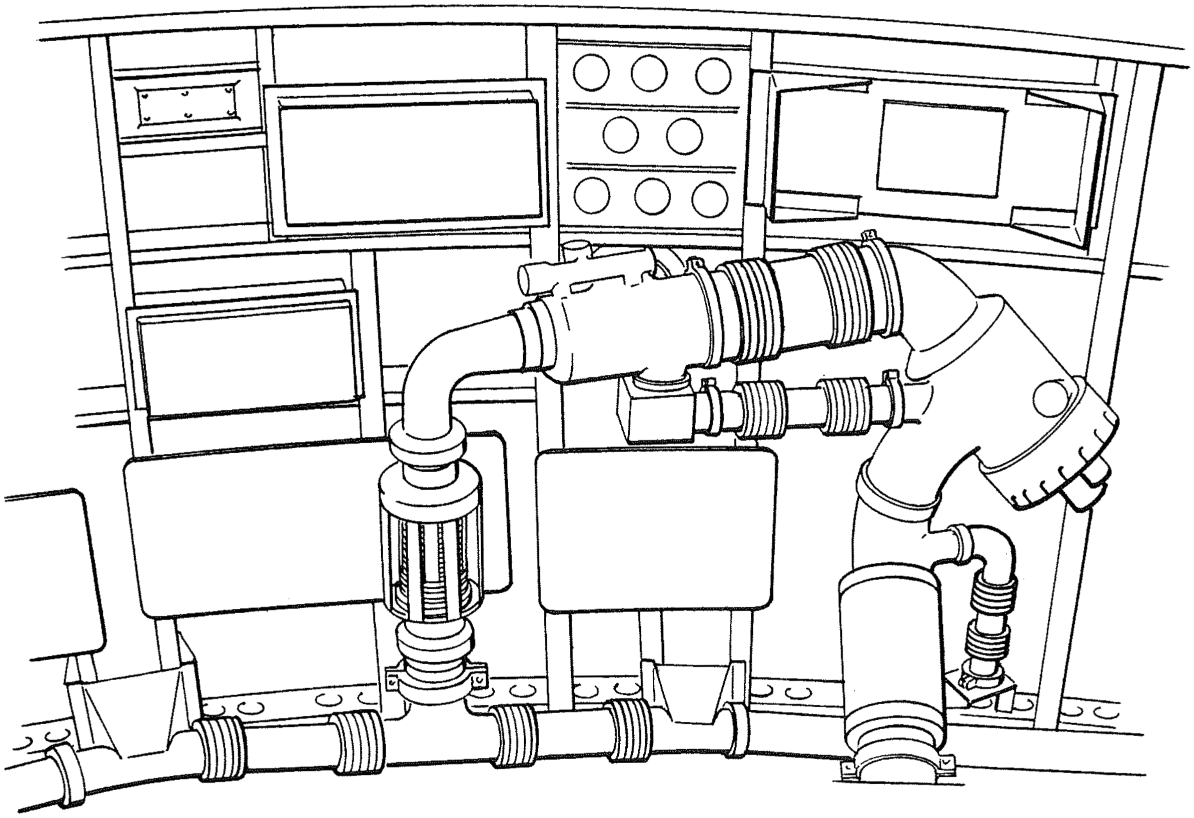


Figure 8. Bellows, P/N 1A49986, Avica

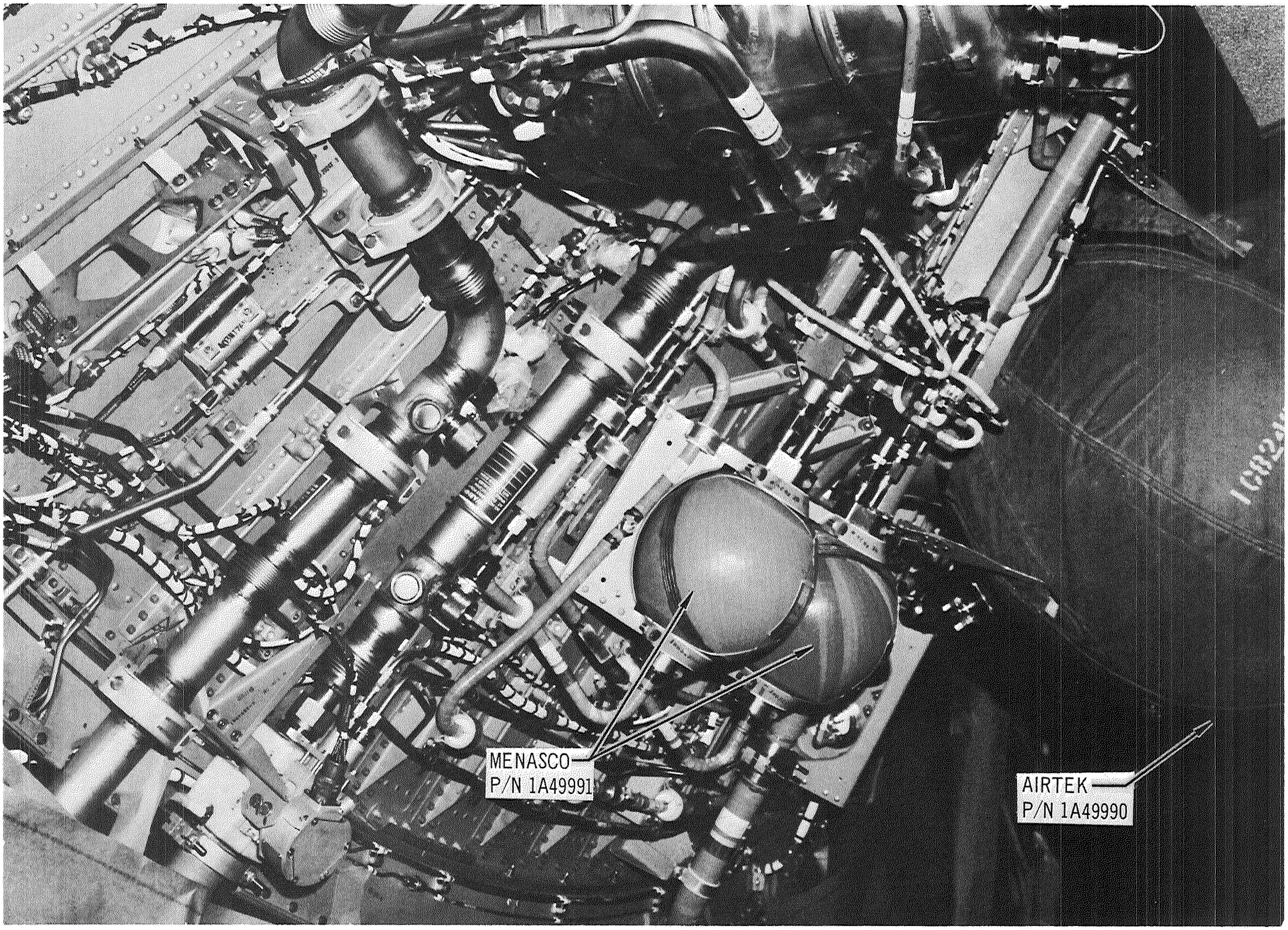


Figure 9. Plenum Spheres and Helium Storage Sphere

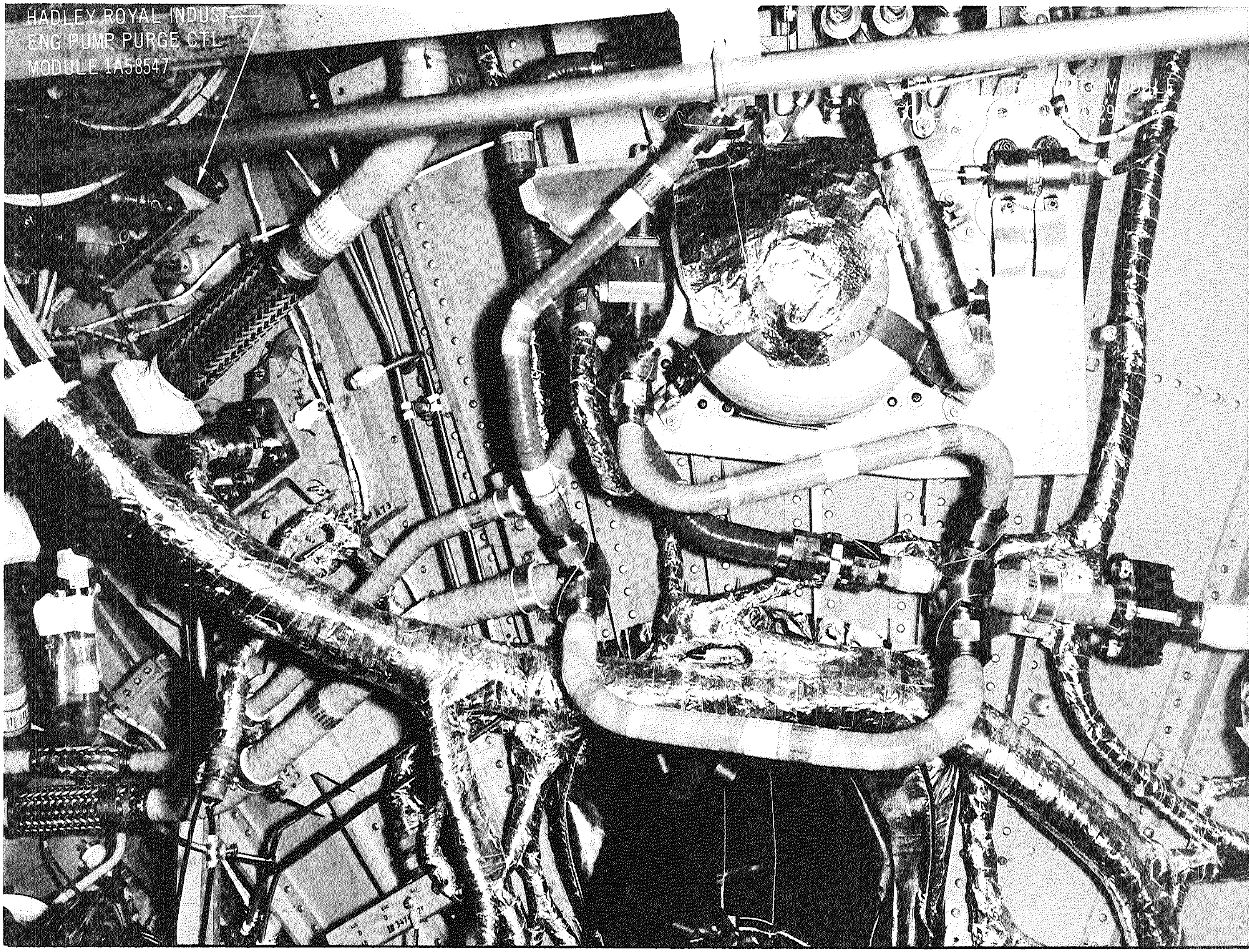


Figure 10. LOX Tank Pressurization System (Sheet 1 of 2)

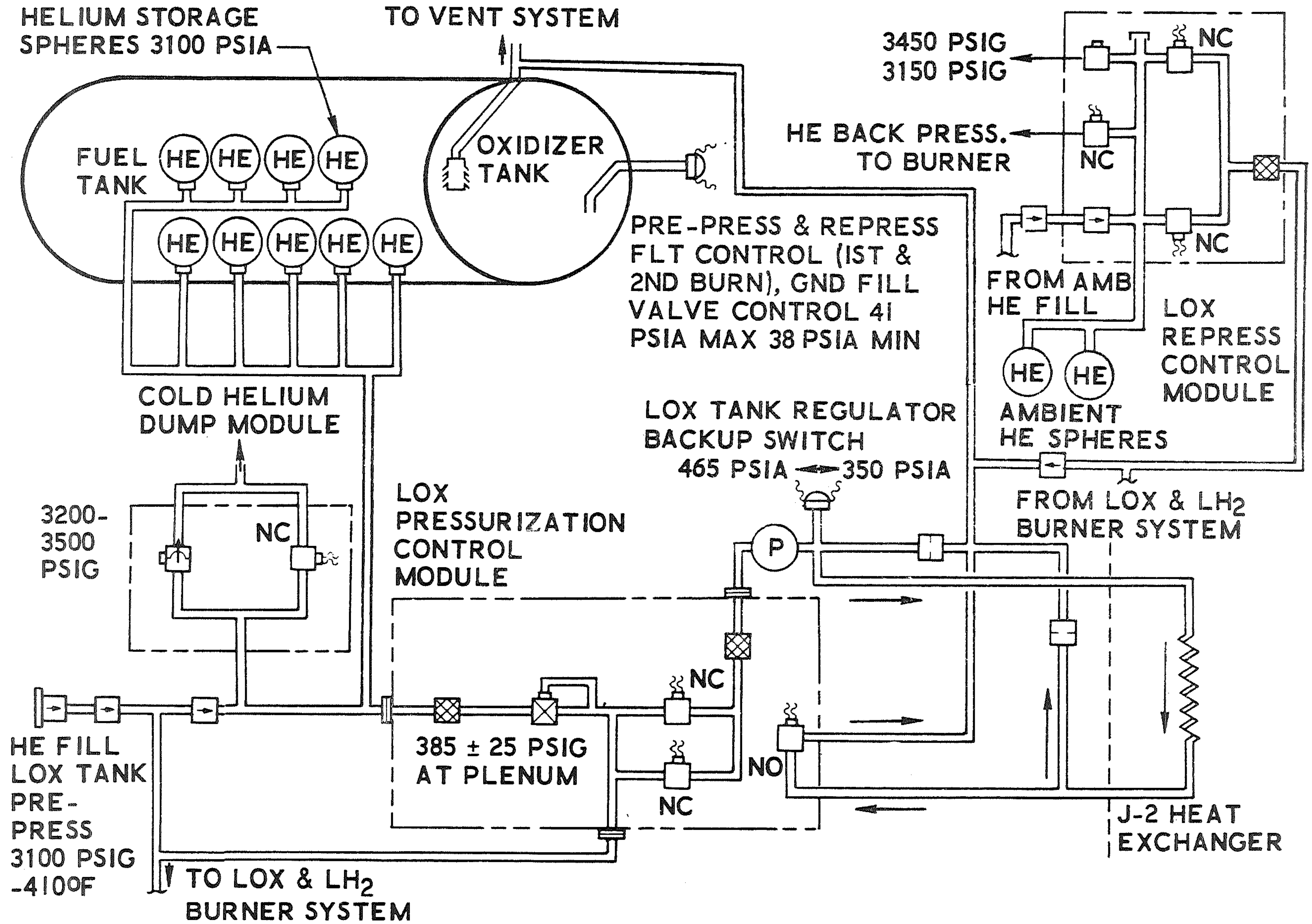


Figure 10. Saturn V/S–IVB Oxidizer Tank Pressurization System (Sheet 2 of 2)

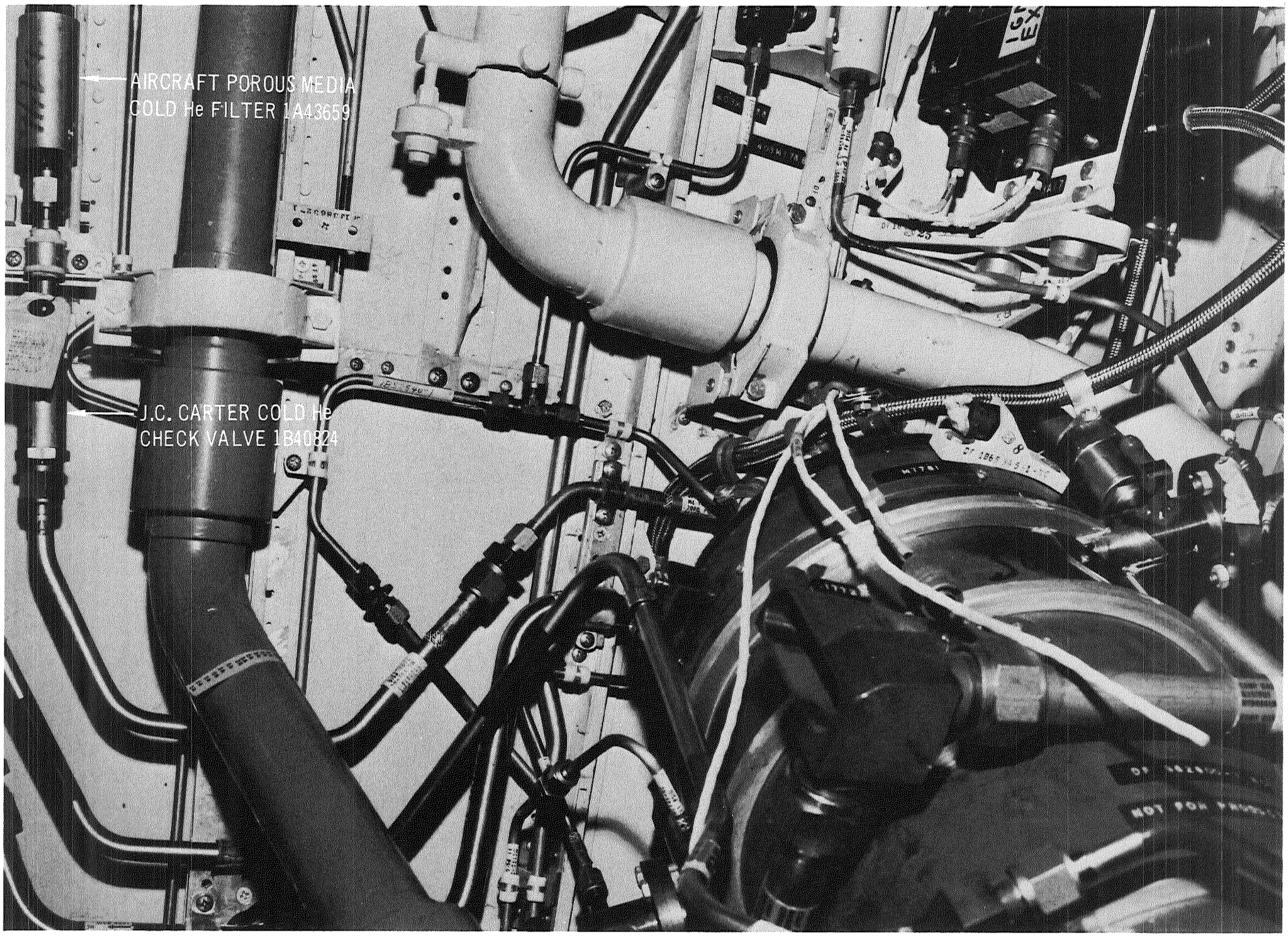


Figure 11. Cold Helium Filter and Check Valve

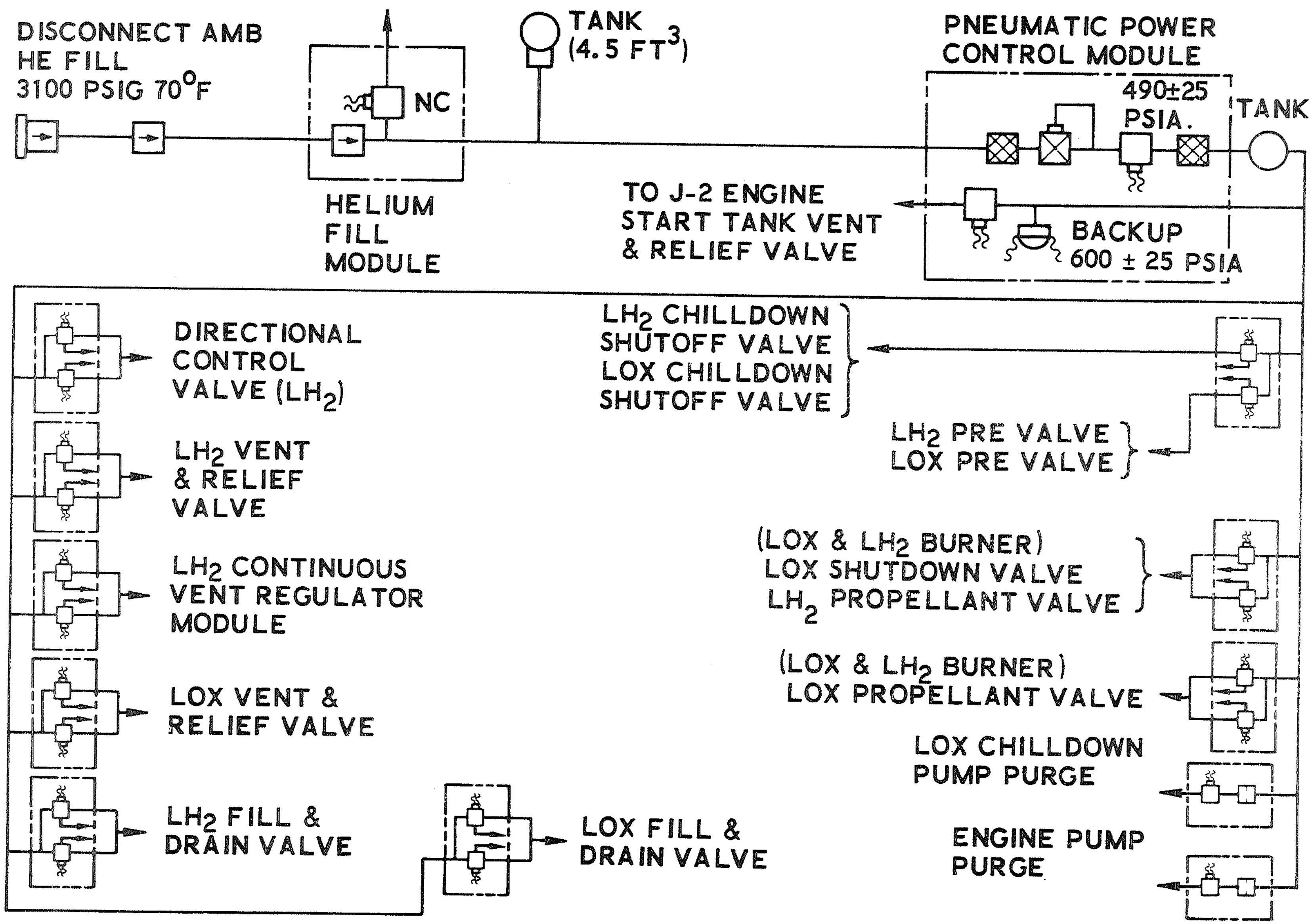


Figure 12. Saturn V/S–IVB Pneumatic Control System

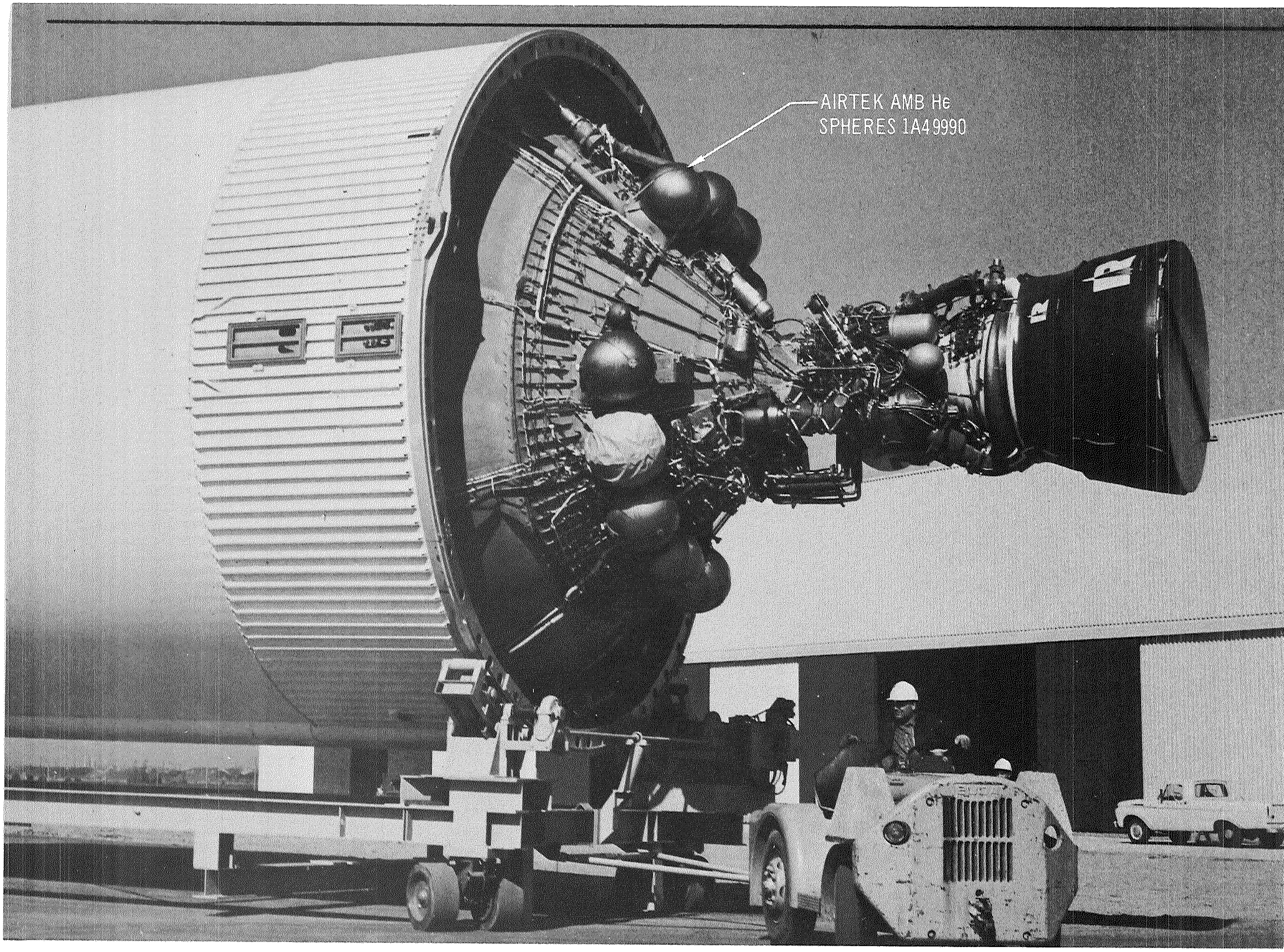


Figure 13. Ambient Helium Spheres

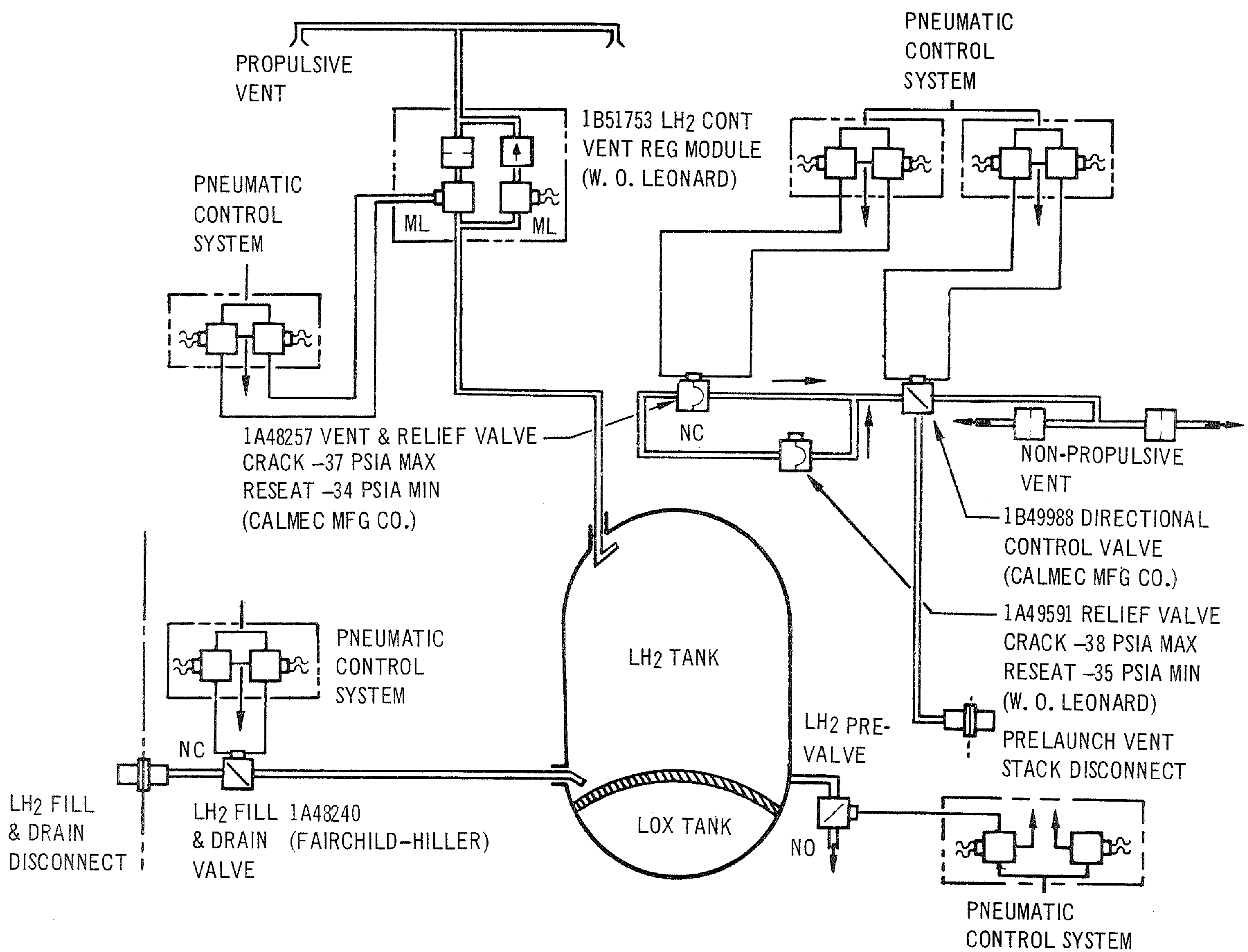


Figure 14. LH2 Fill, Drain, Feed and Vent

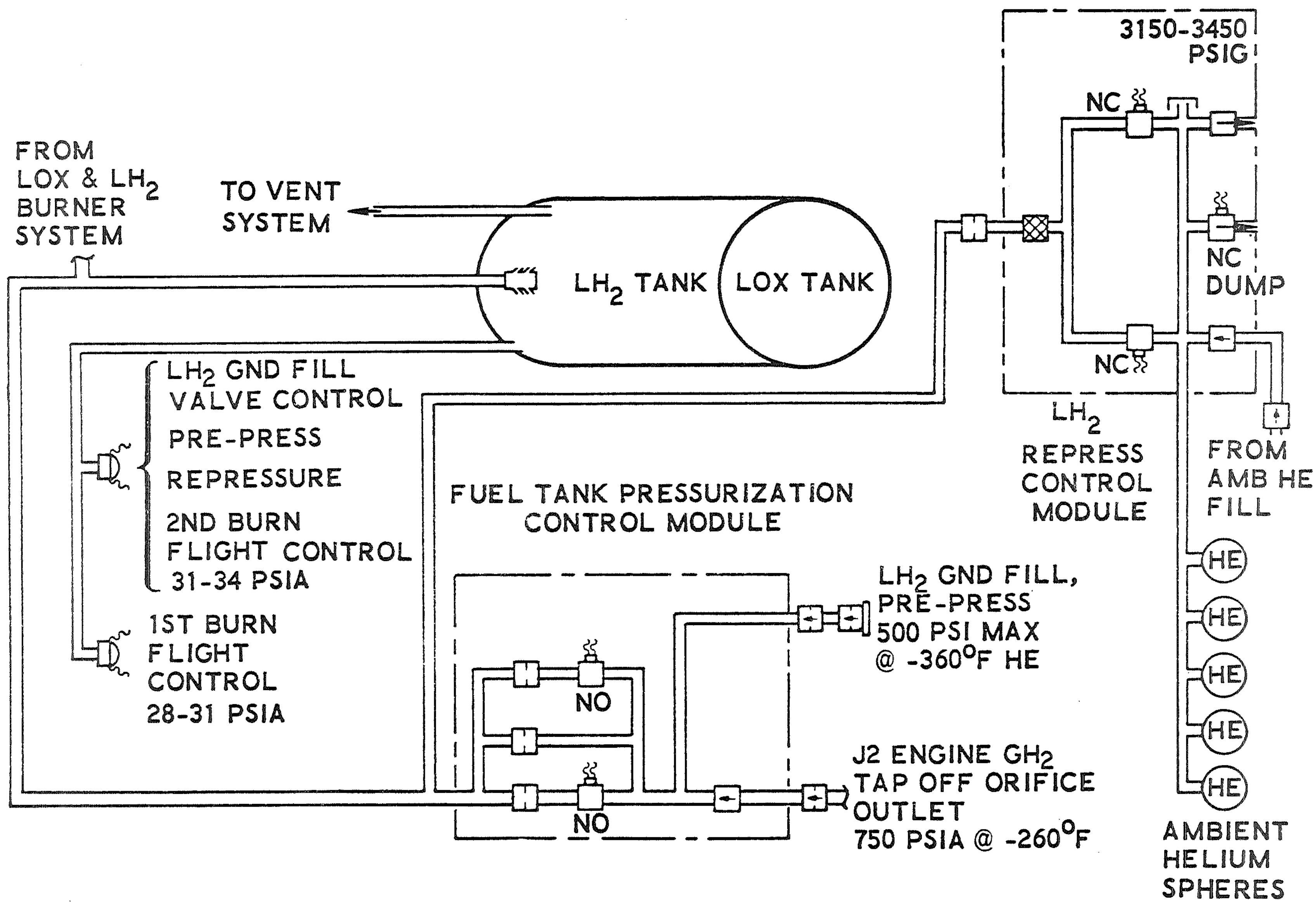


Figure 15. Saturn V/S–IVB Fuel Tank Pressurization System

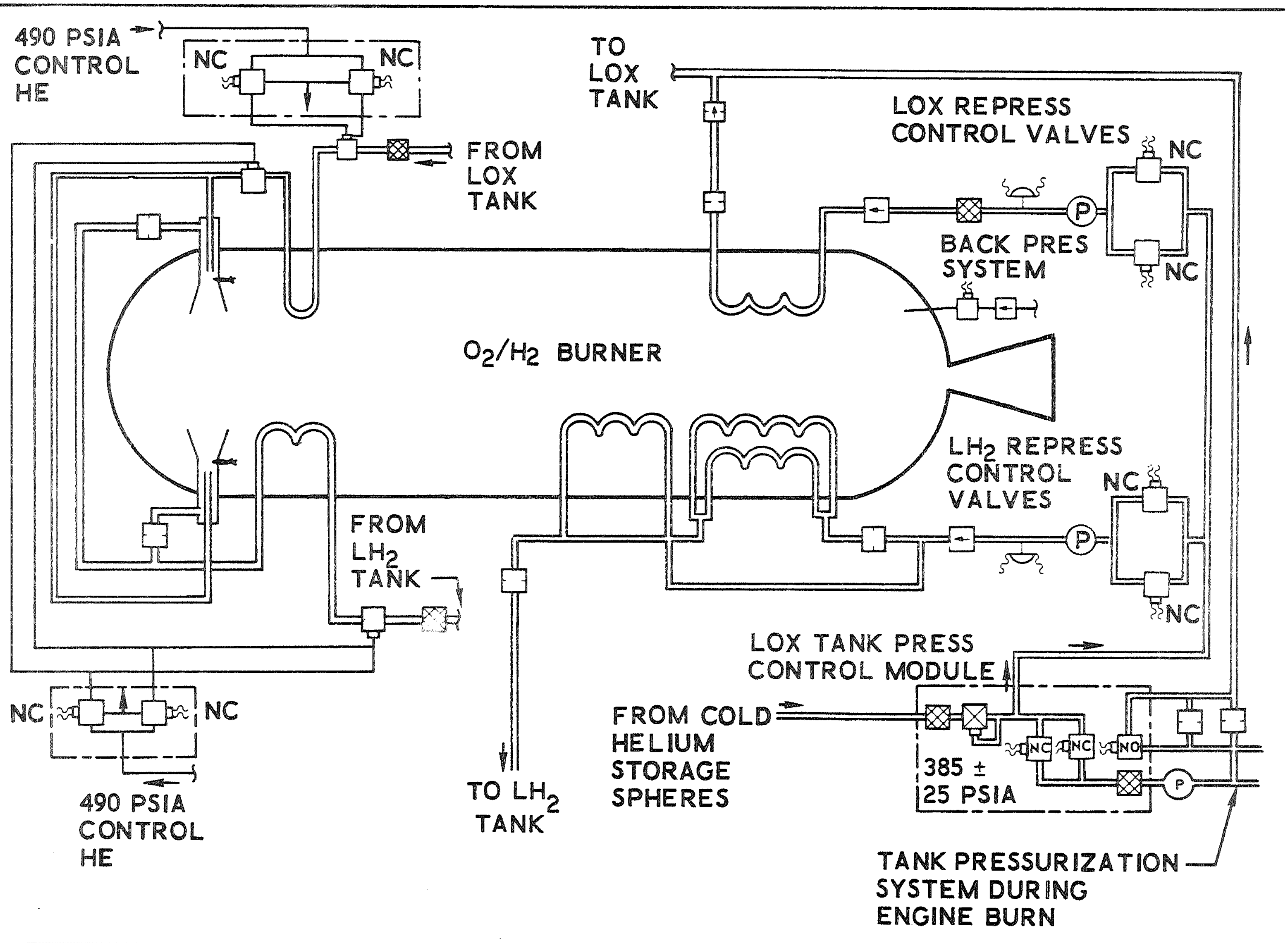


Figure 16. O2/H2 Burner Configuration

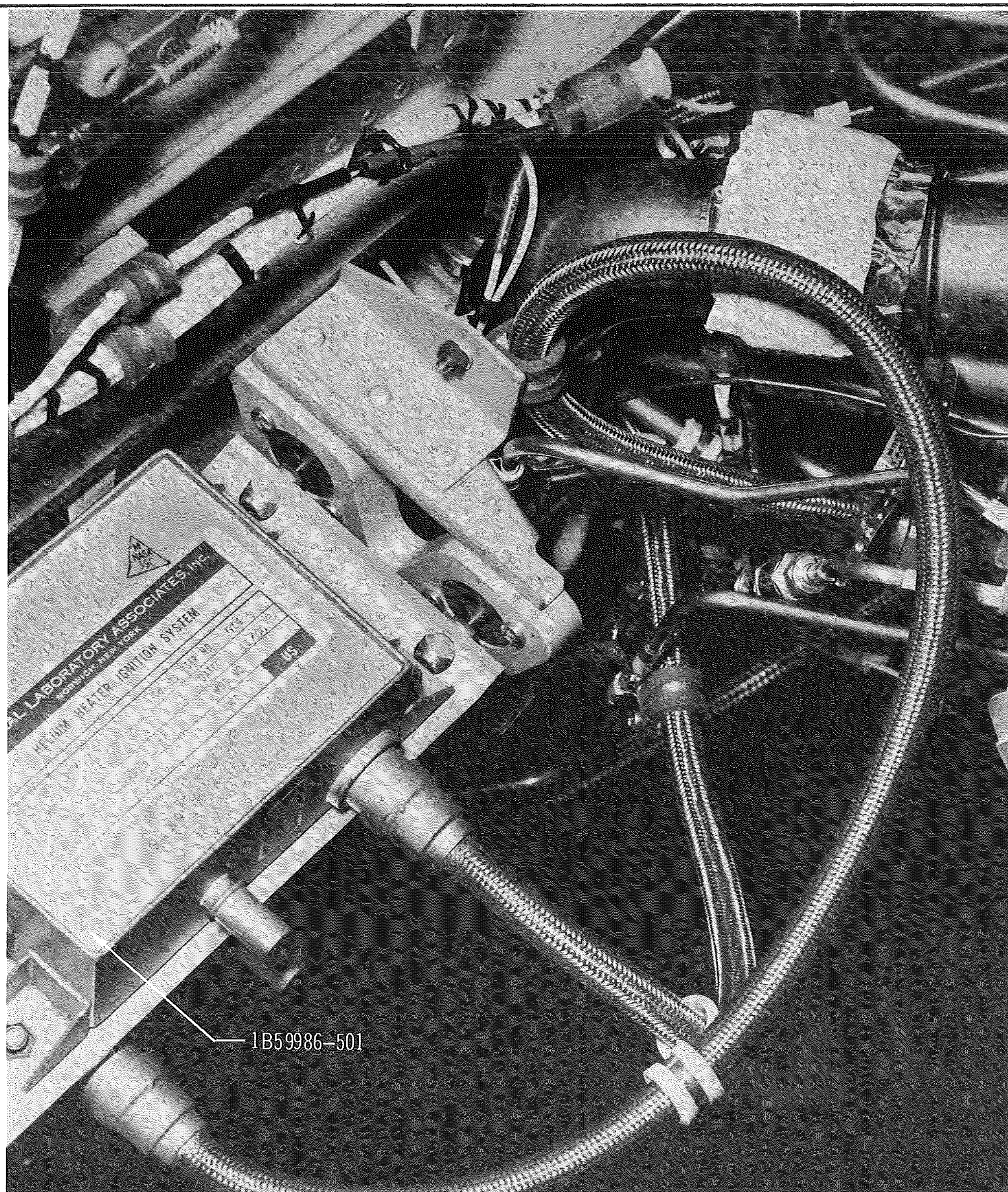


Figure 17. O2/H2 Burner Ignition System

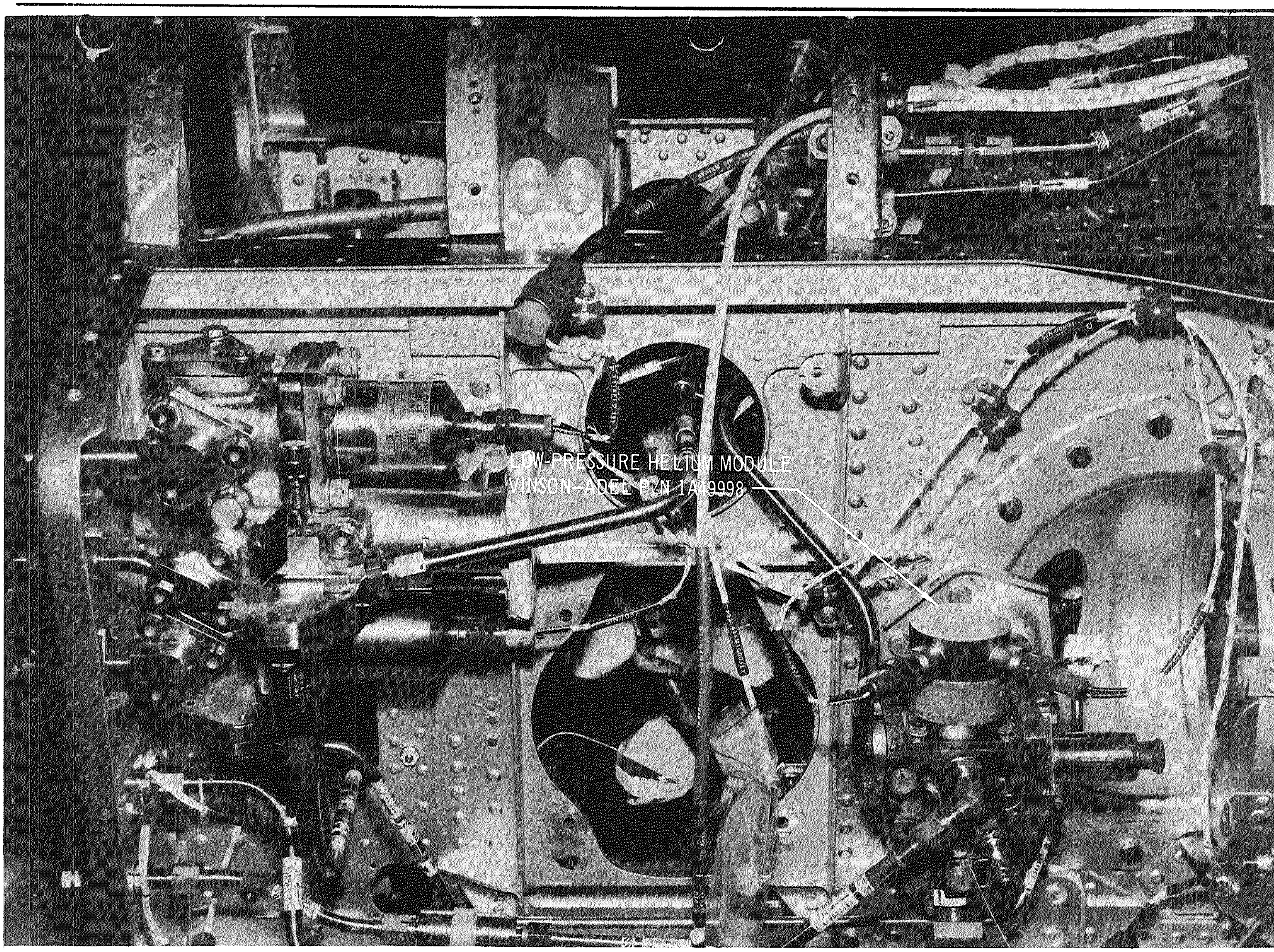


Figure 18. Attitude and Roll Control Engine

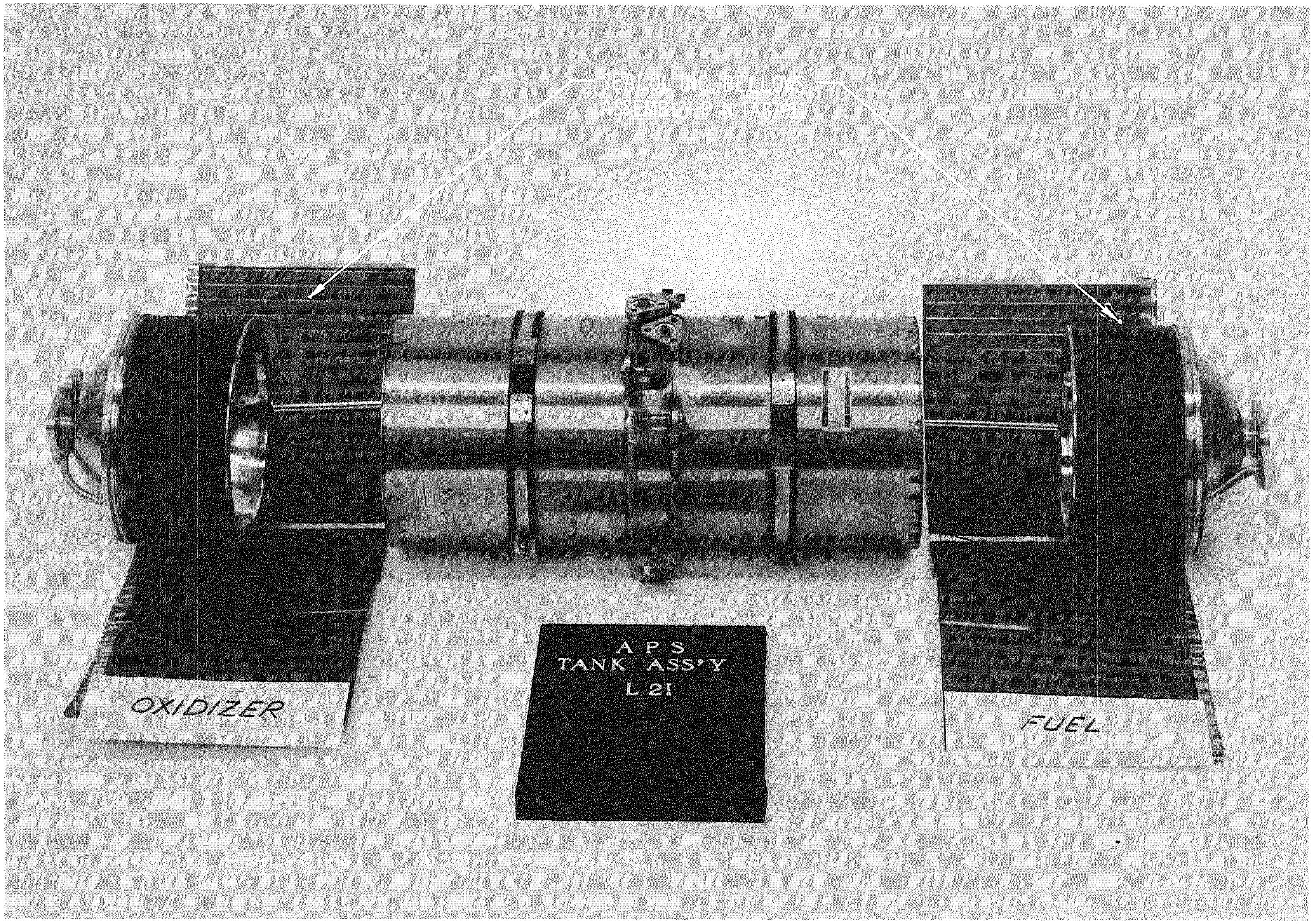


Figure 19. Stainless Steel Bellows

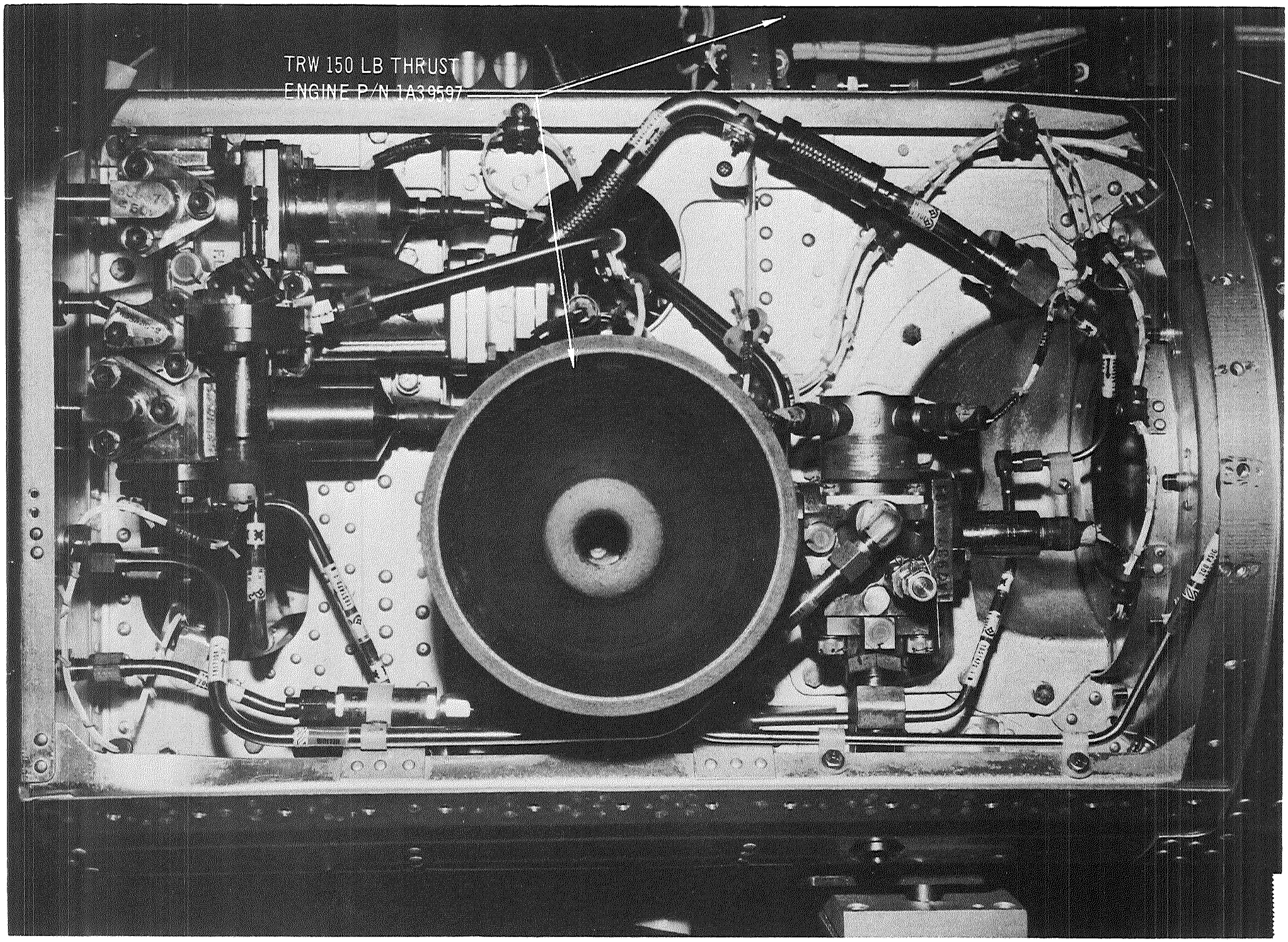


Figure 20. Low-Pressure Helium Module

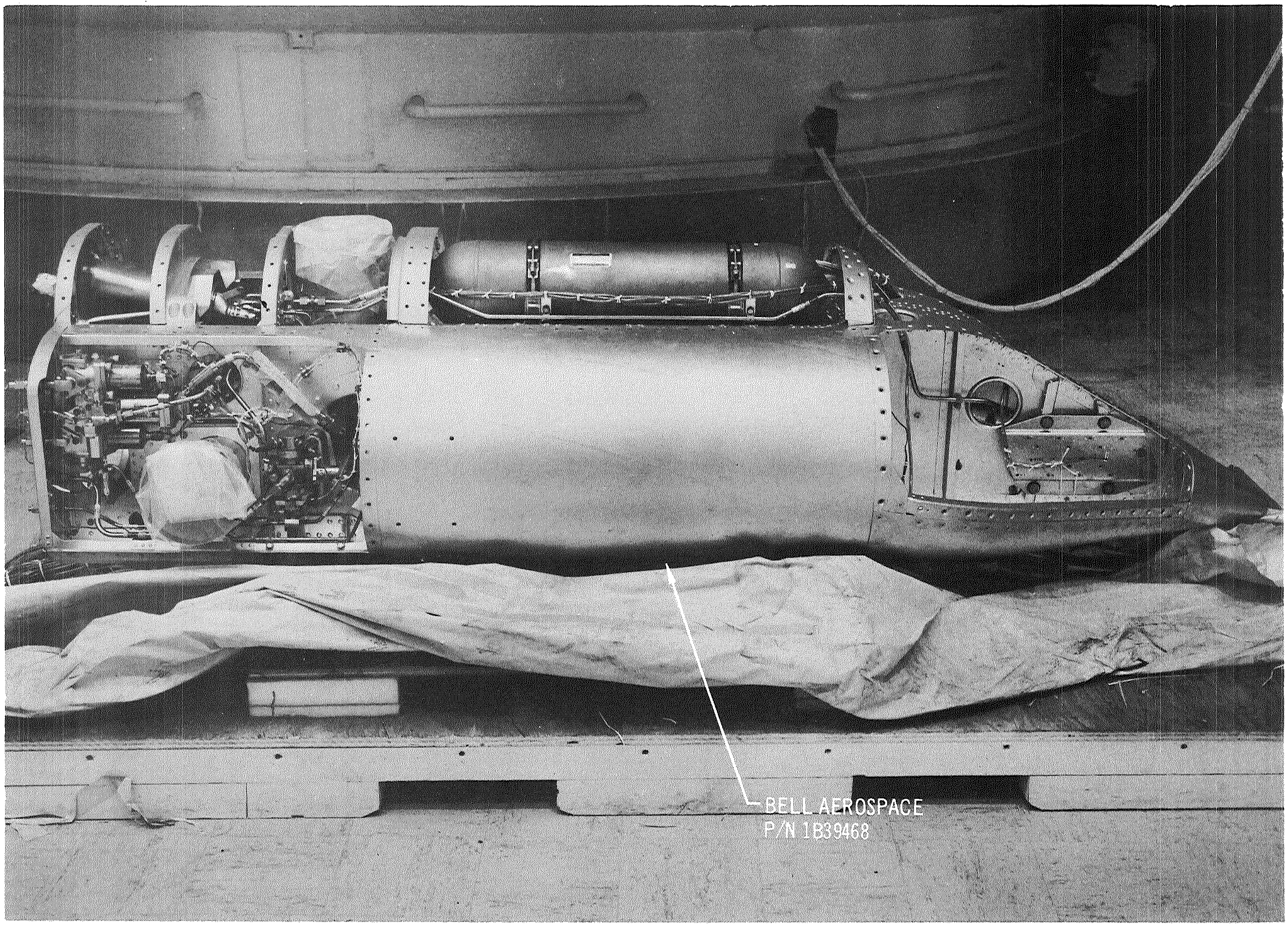


Figure 21. APS Positive Expulsion Bladder and Tank Assembly

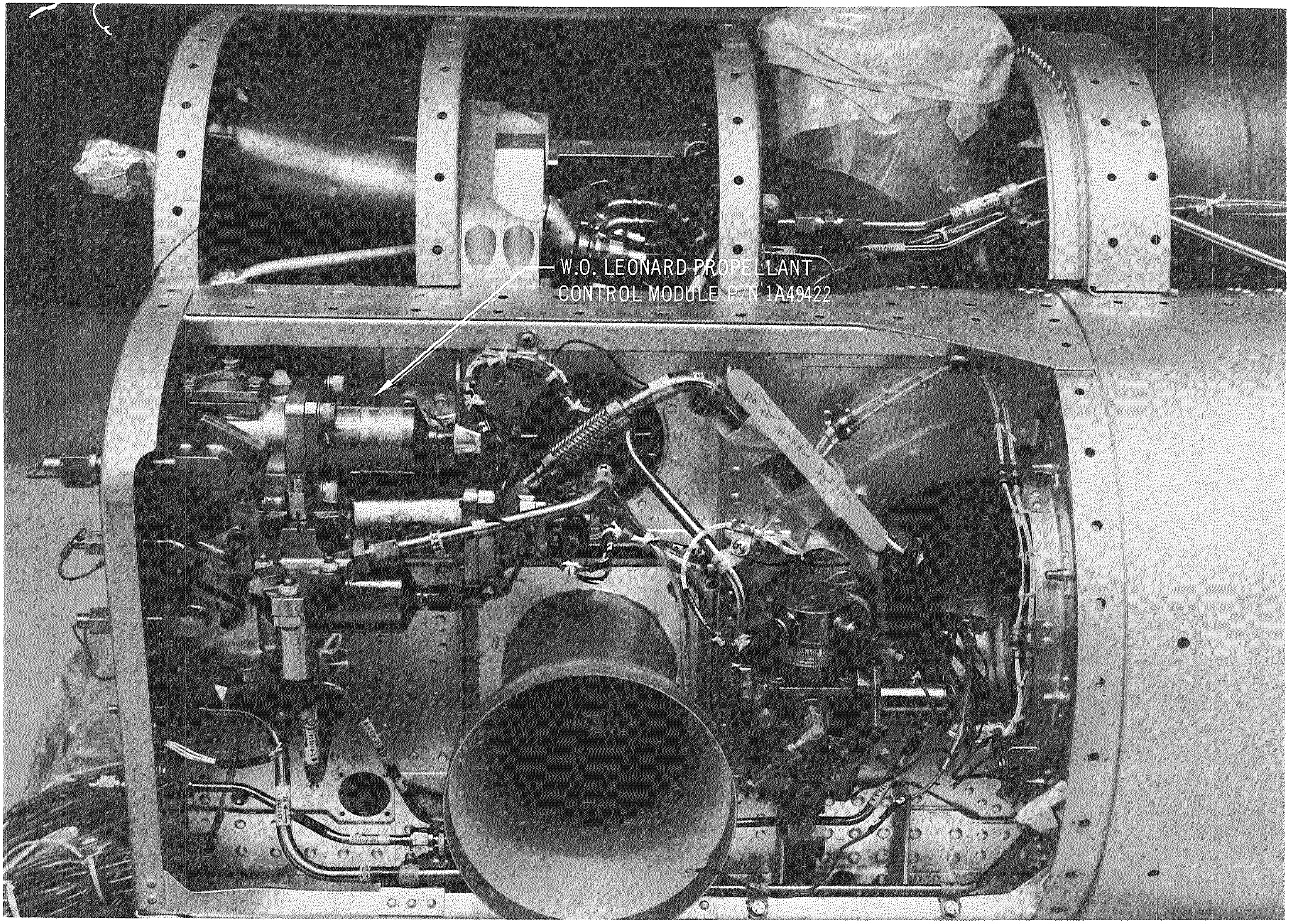


Figure 22. Propellant Control Module

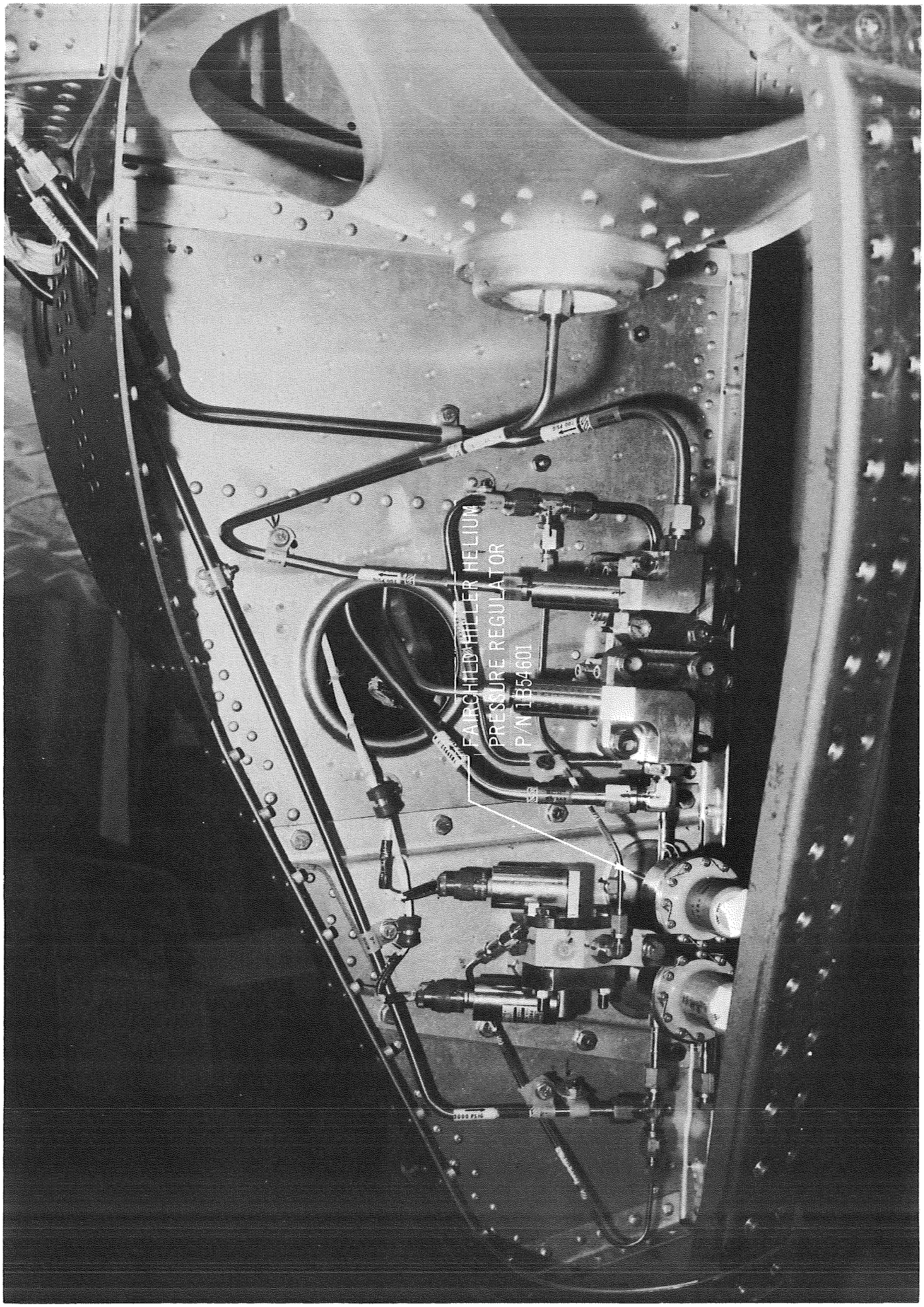


Figure 23. APS Helium Pressure Regulator

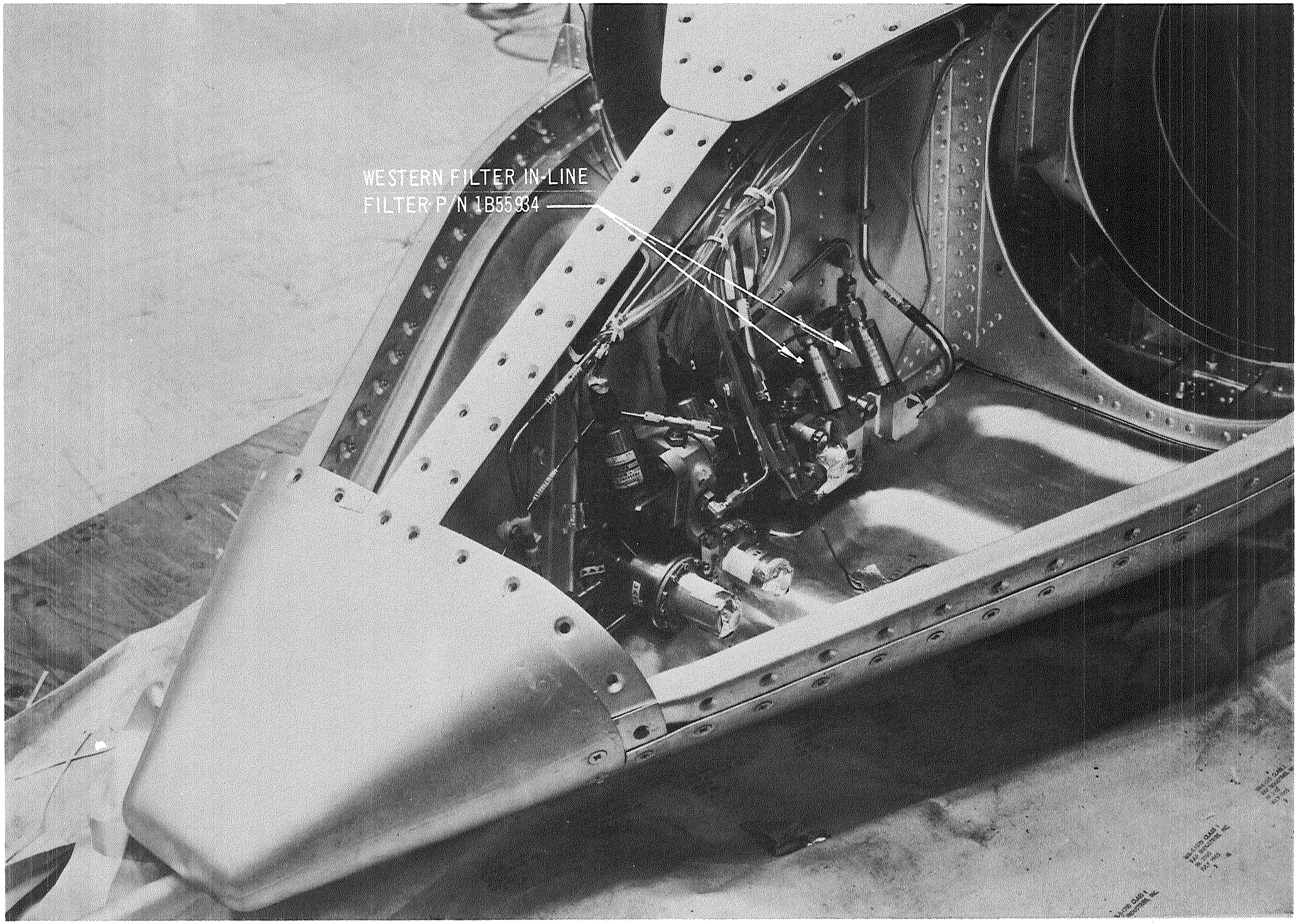


Figure 24. In-Line Filter

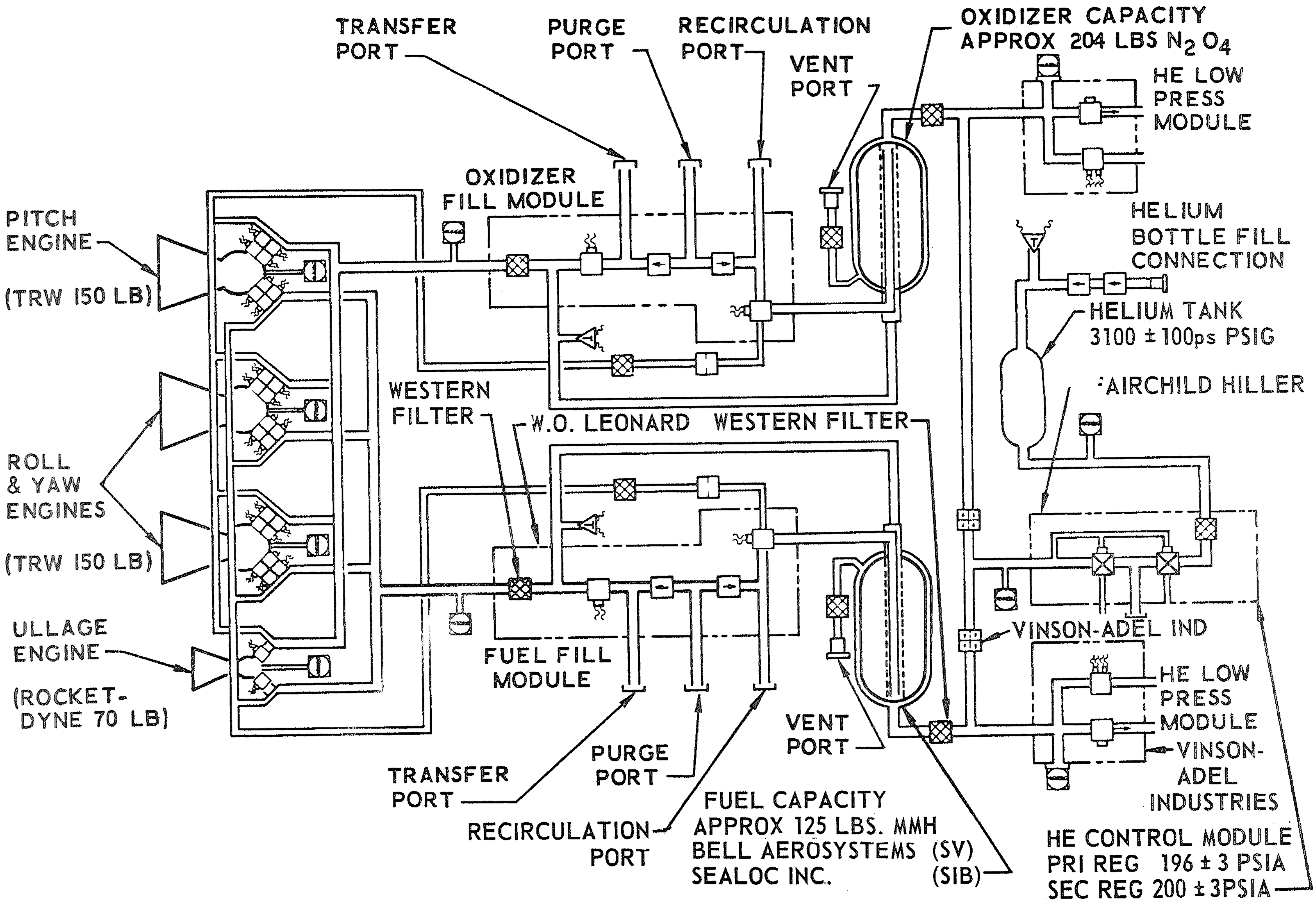


Figure 25. APS Schematic

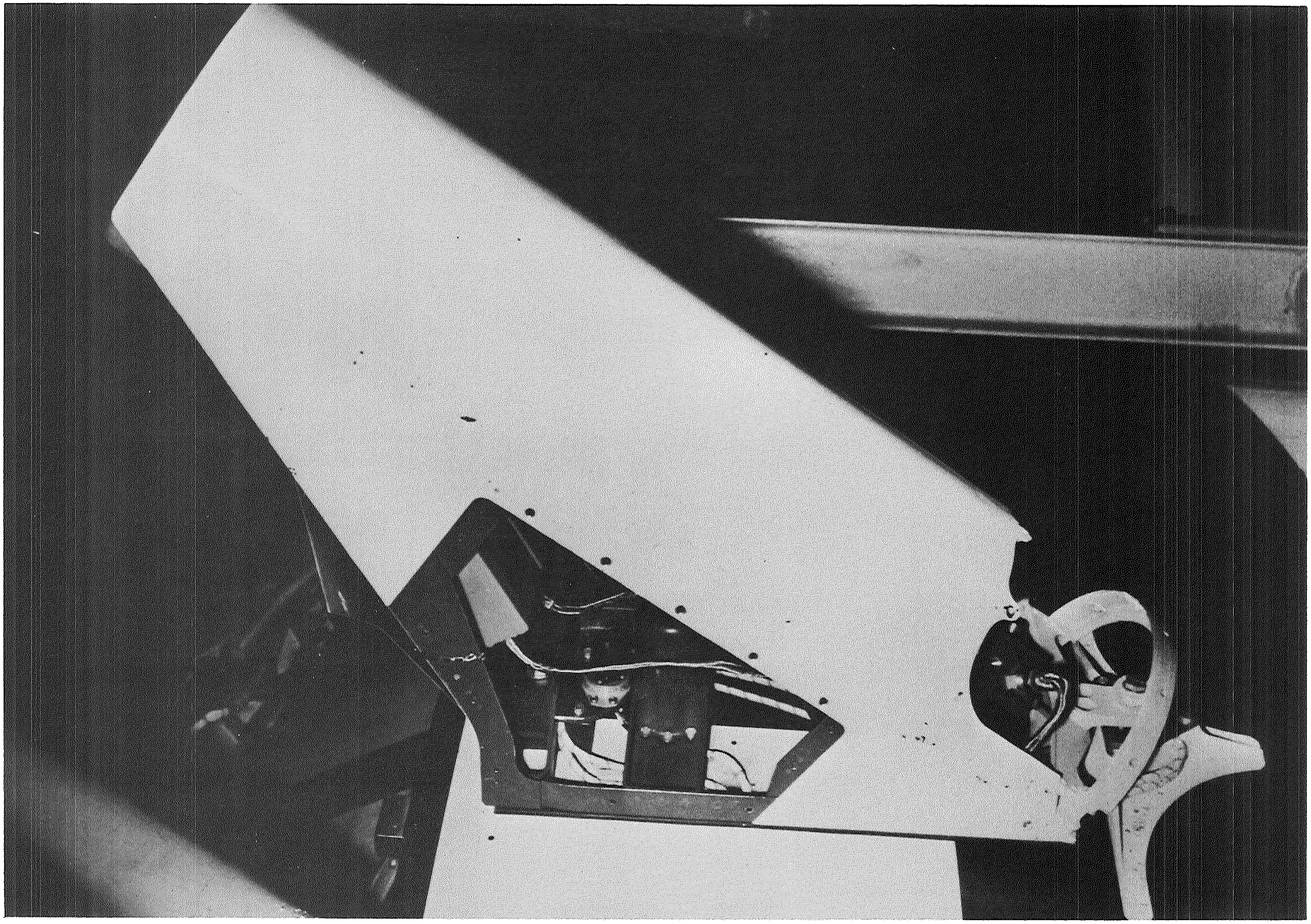


Figure 26. Ullage Rocket Motor

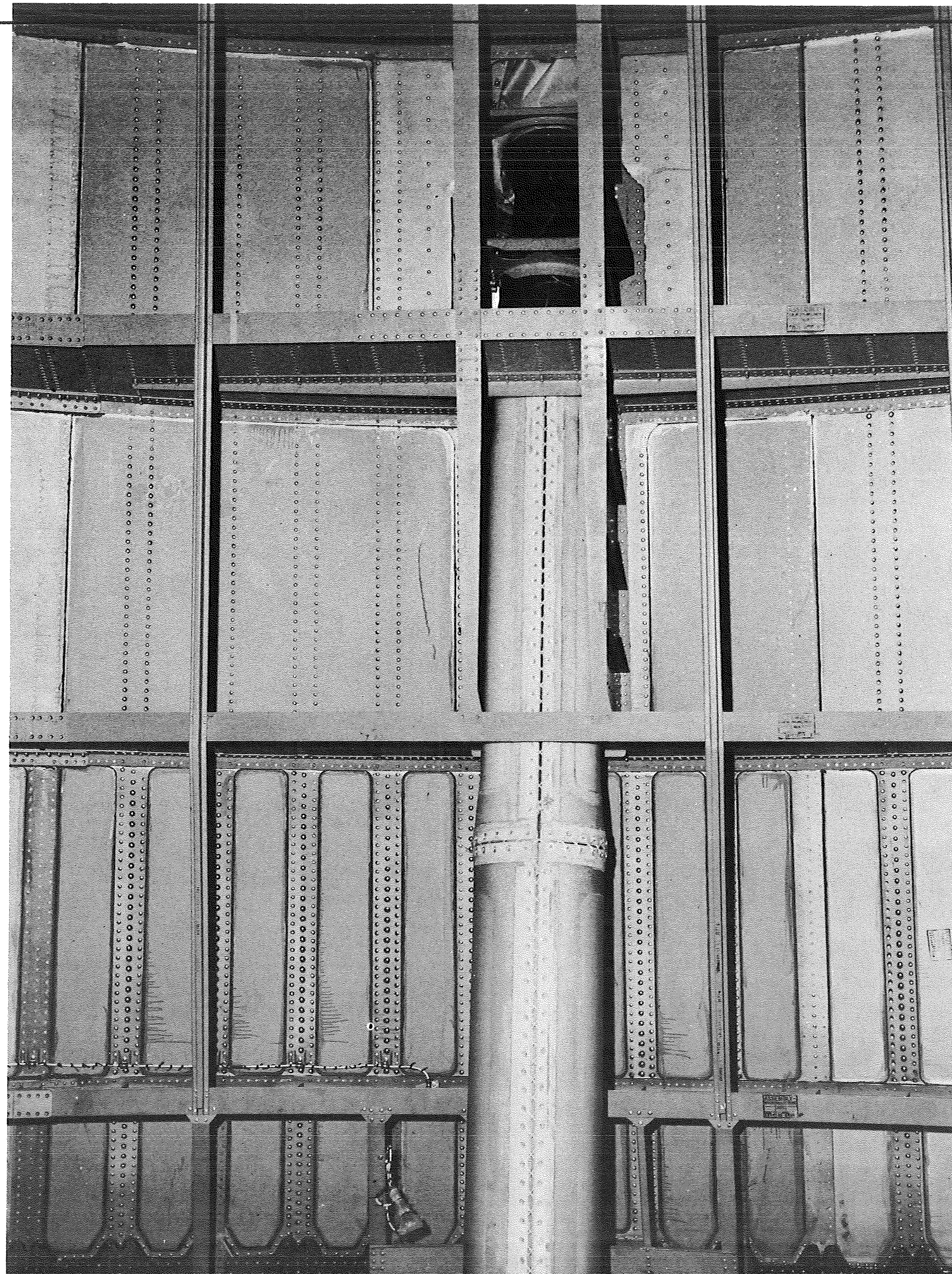


Figure 27. Retrorocket Motor, Saturn V

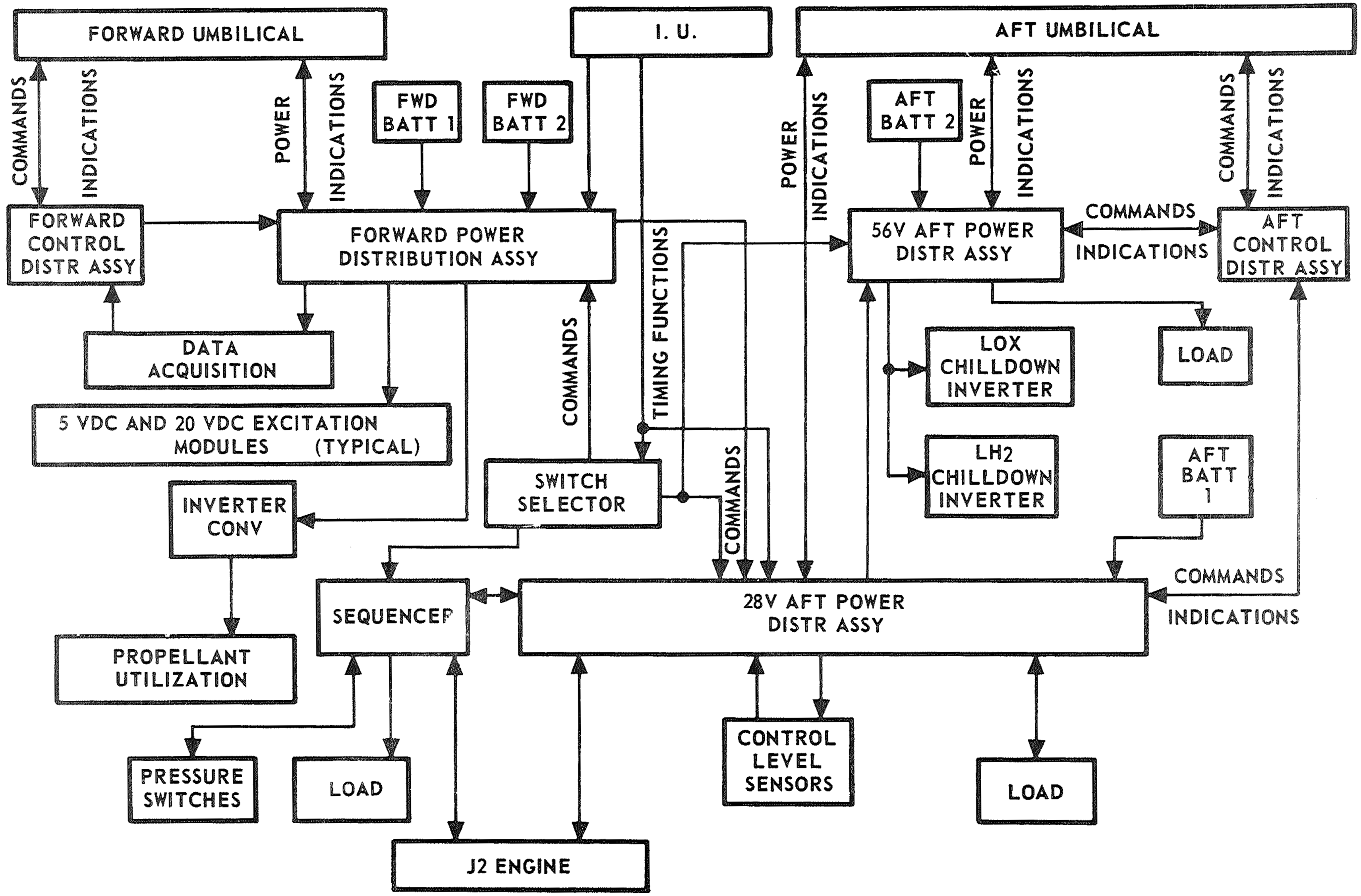


Figure 28. Electrical System

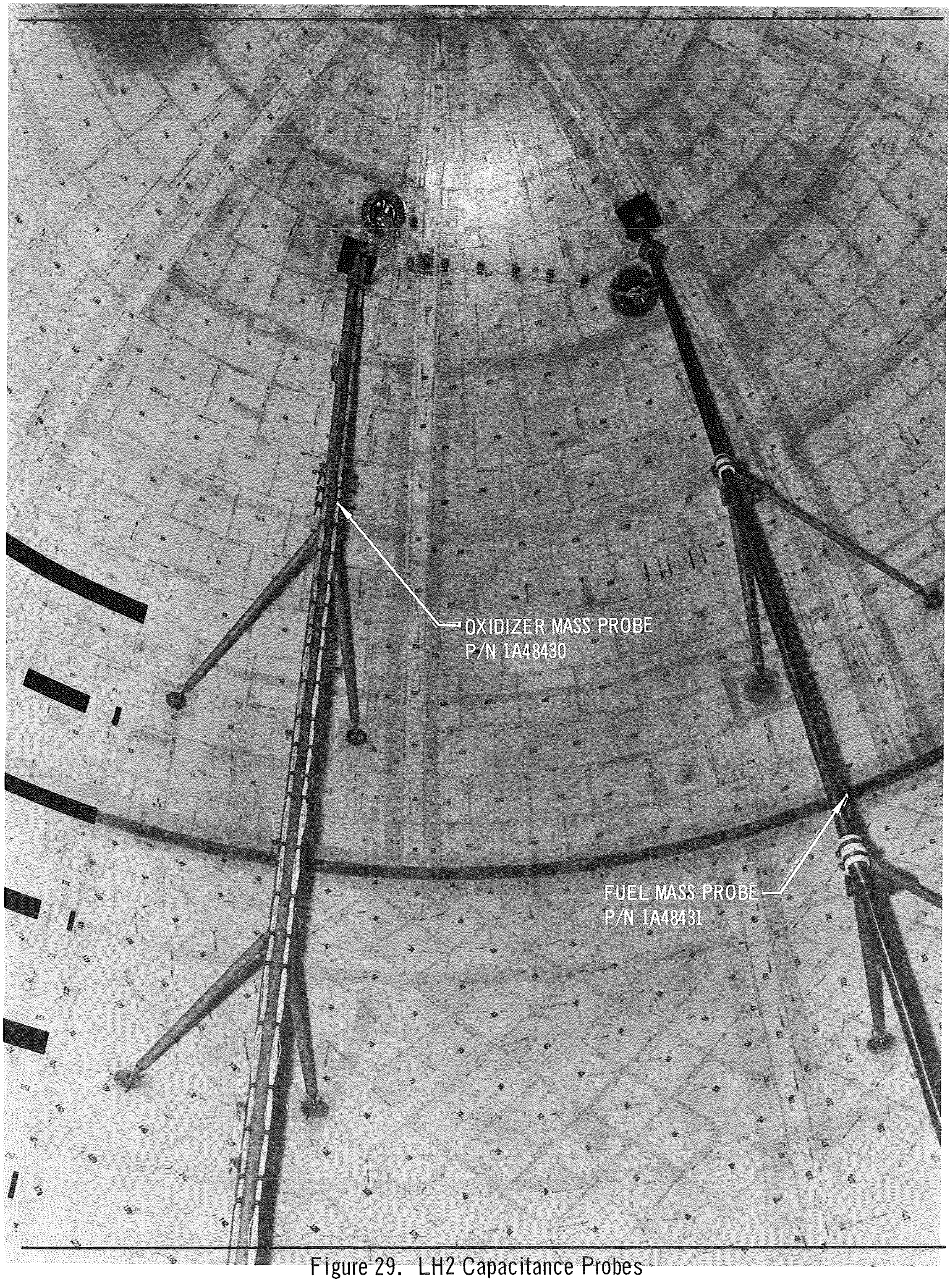


Figure 29. LH2 Capacitance Probes

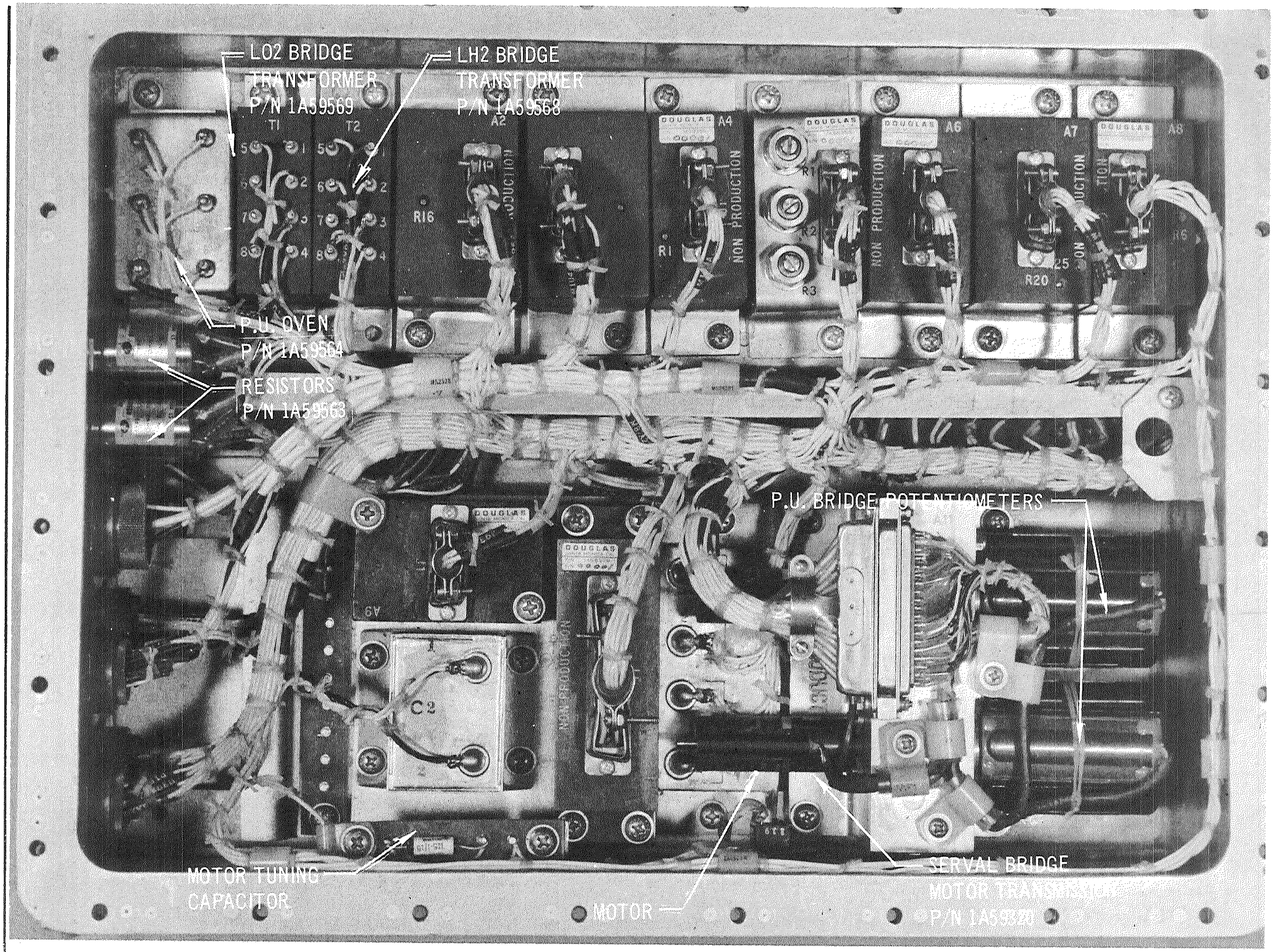


Figure 30. P.U. Electronics Assembly

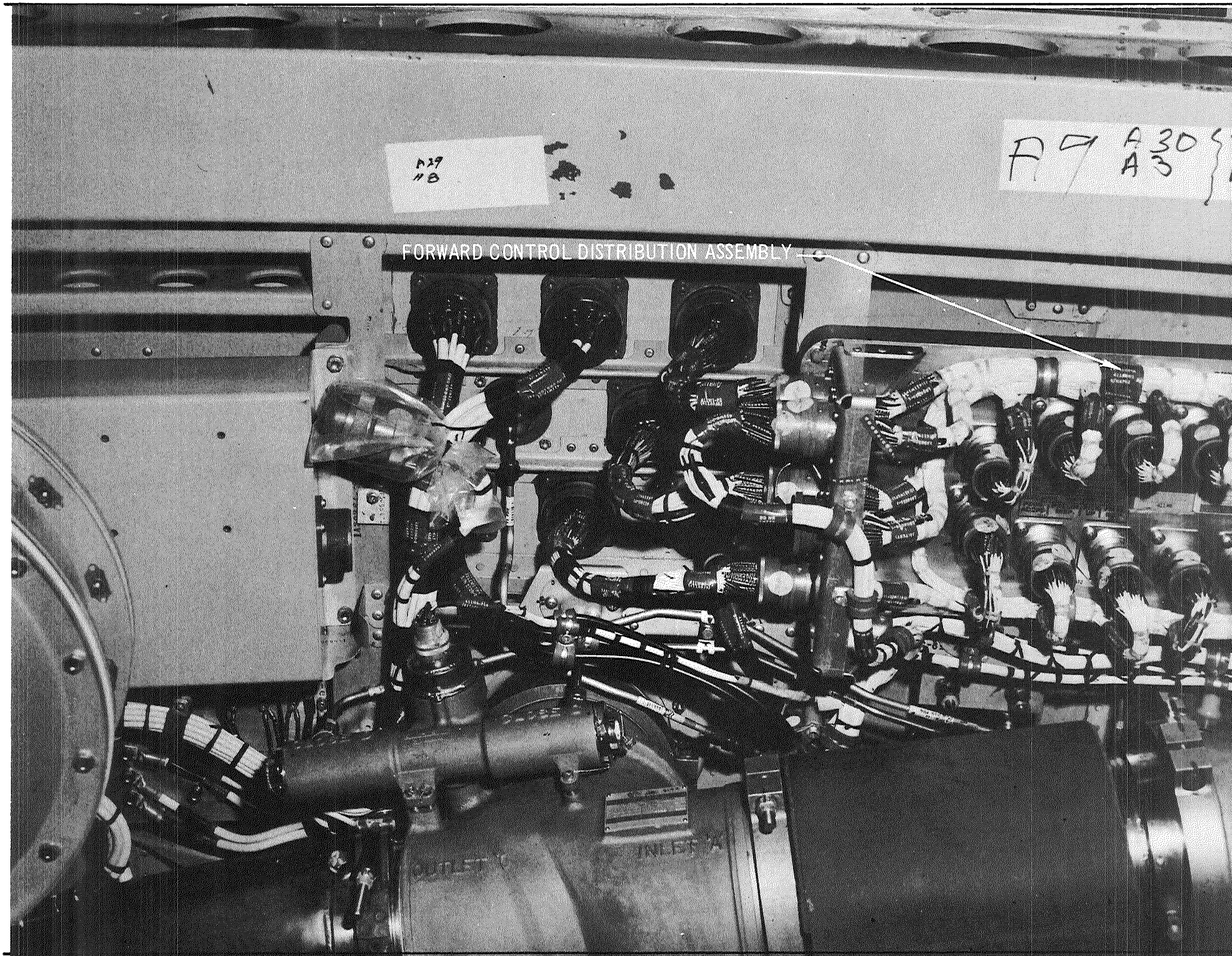


Figure 31. Forward Control Distribution Assembly

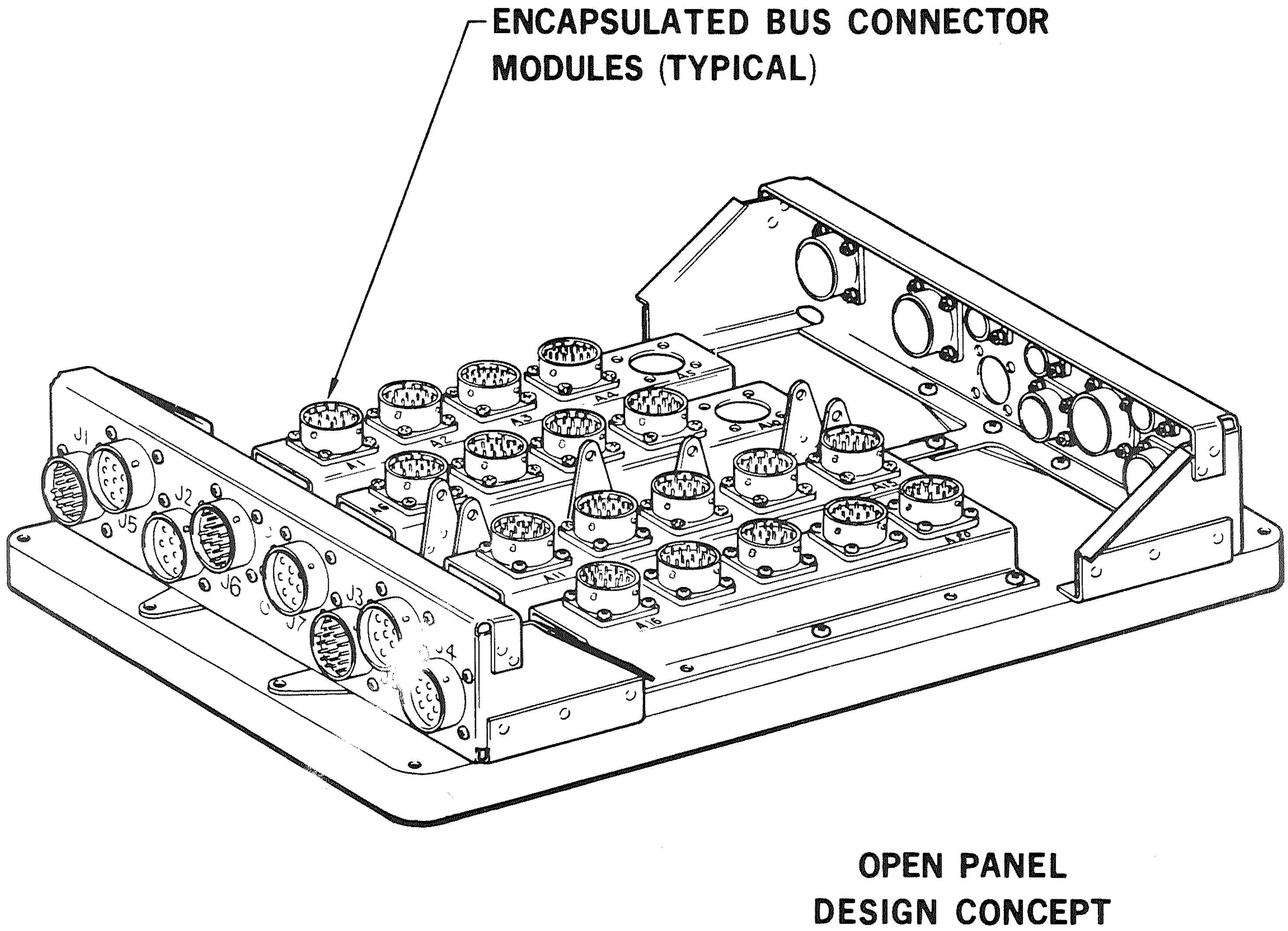


Figure 32. Aft Control Distribution Assembly

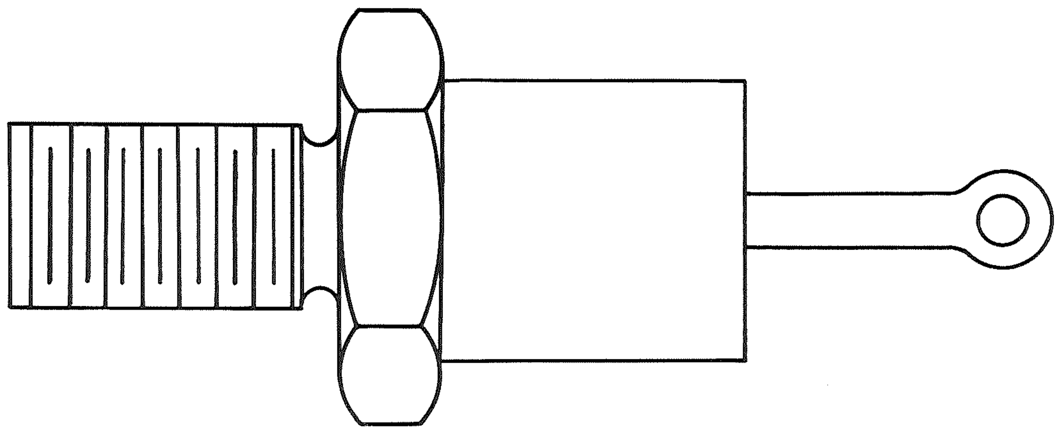


Figure 33. Semiconductor Device – Diode Power BENDIX P/N 1B54541

Figure 34. Aft Distribution Panel 28 VDC

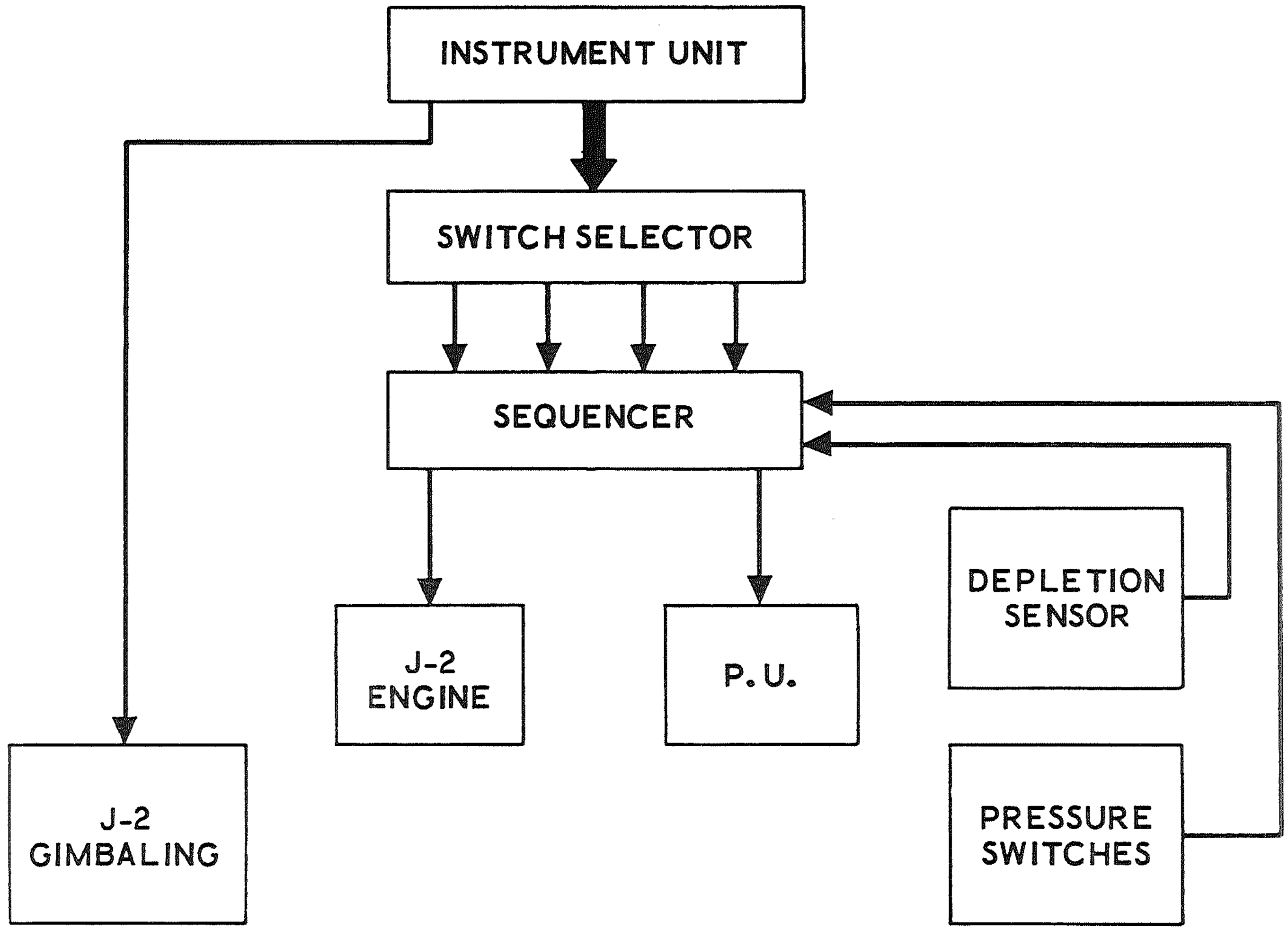


Figure 35. S–IVB Stage Sequencing System

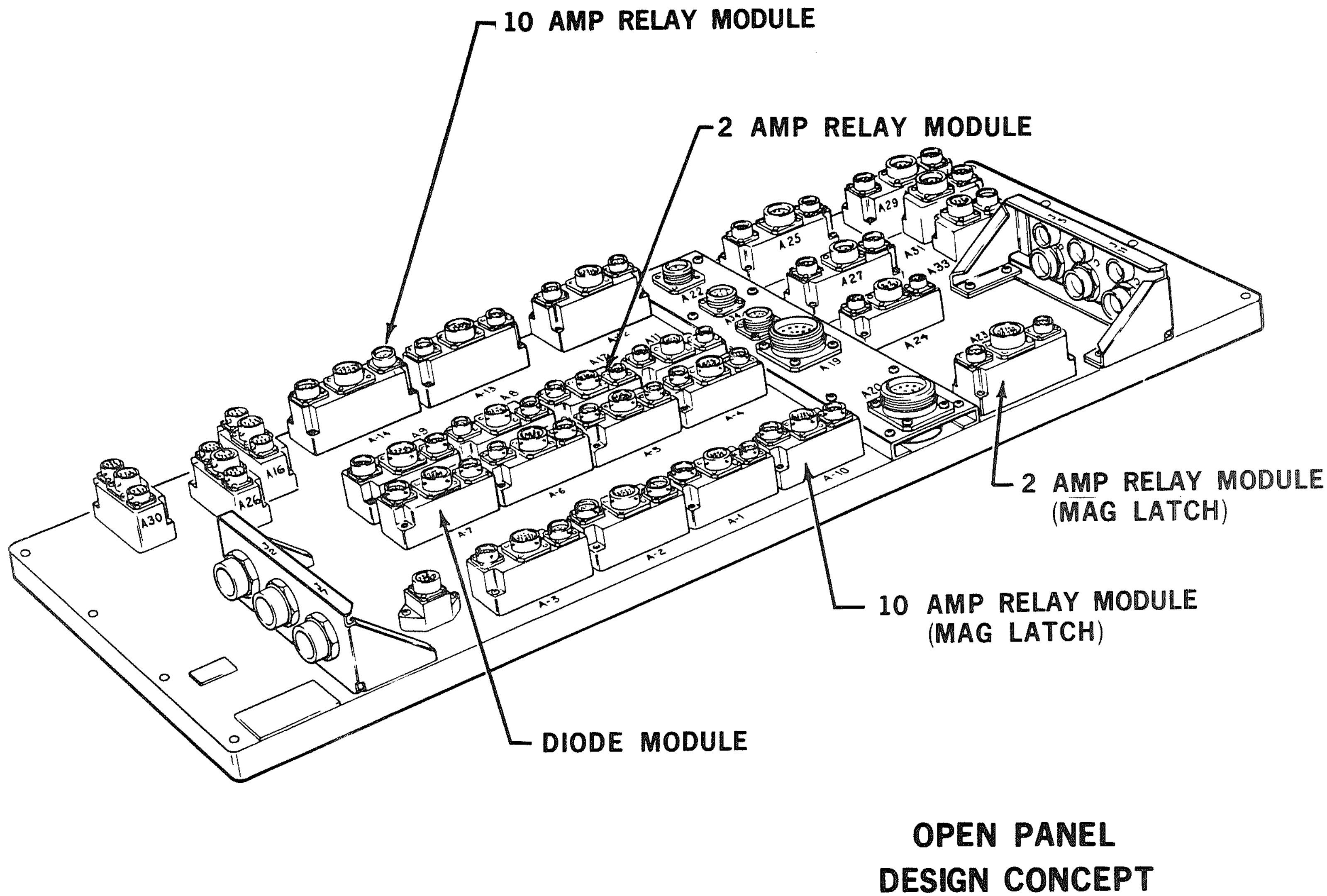


Figure 36. S–IVB Sequencer Mounting Assembly

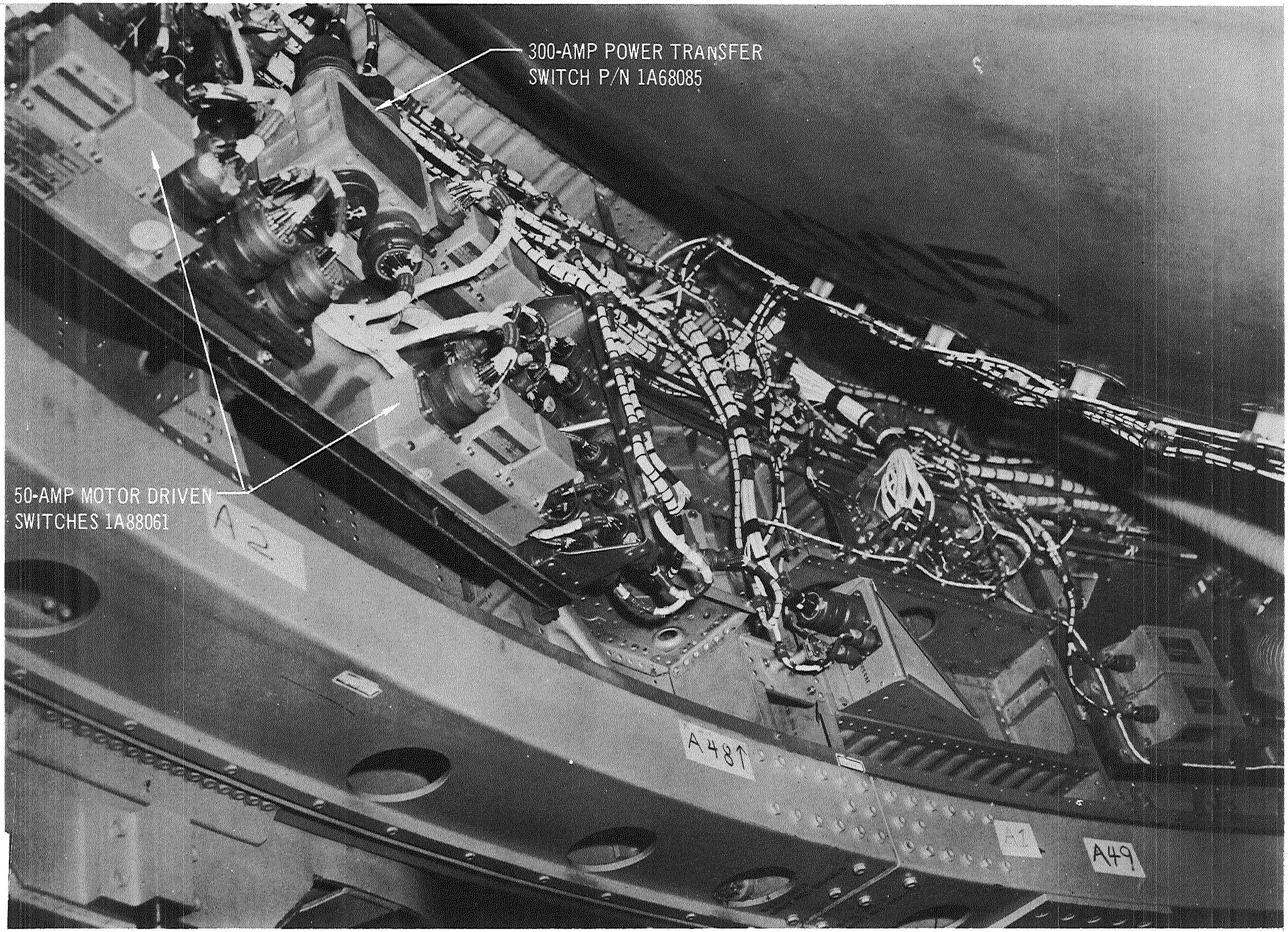


Figure 37. S–IVB Sequencing Panel

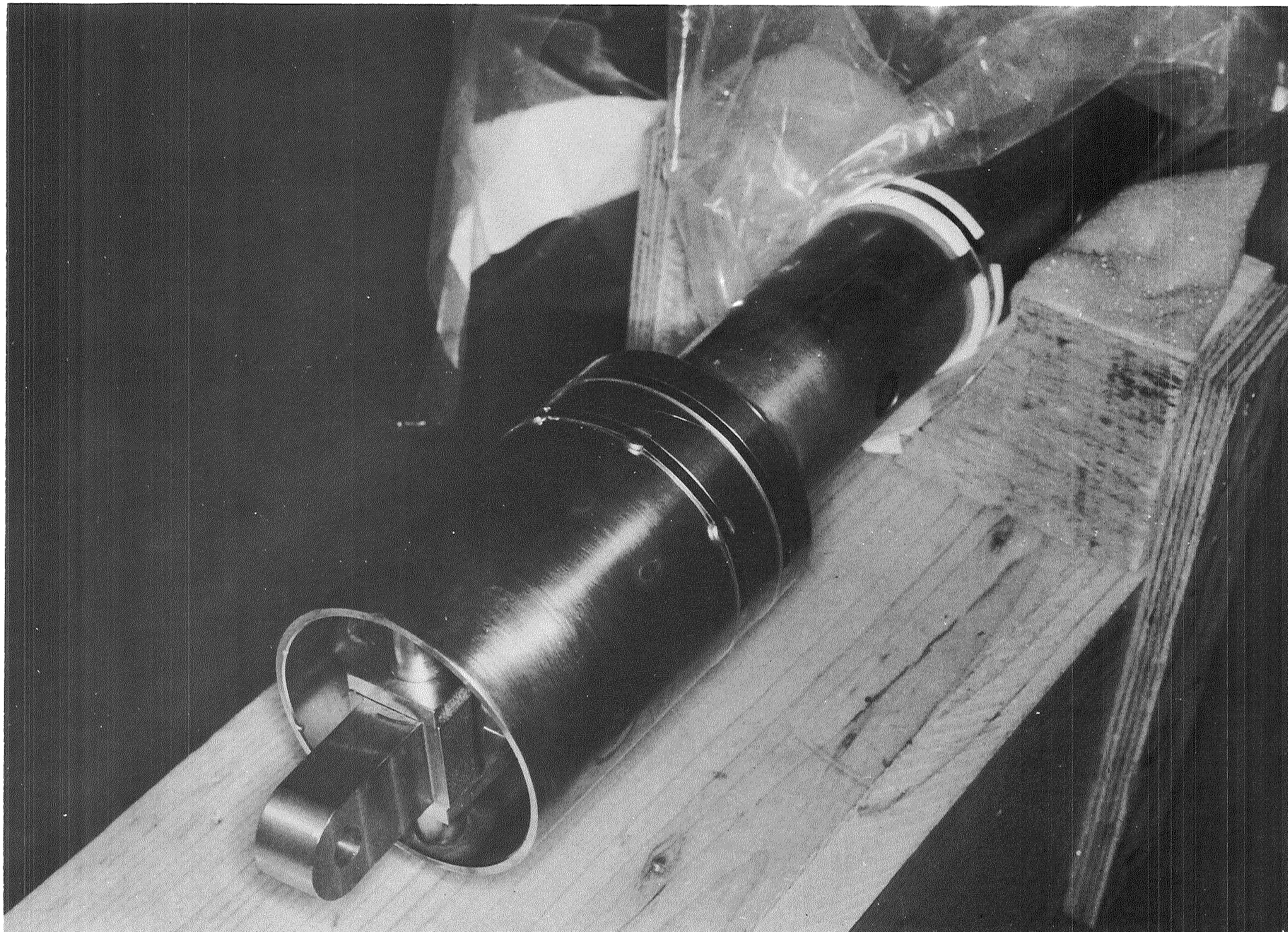


Figure 38. Motor Starter Switch, 1B32647

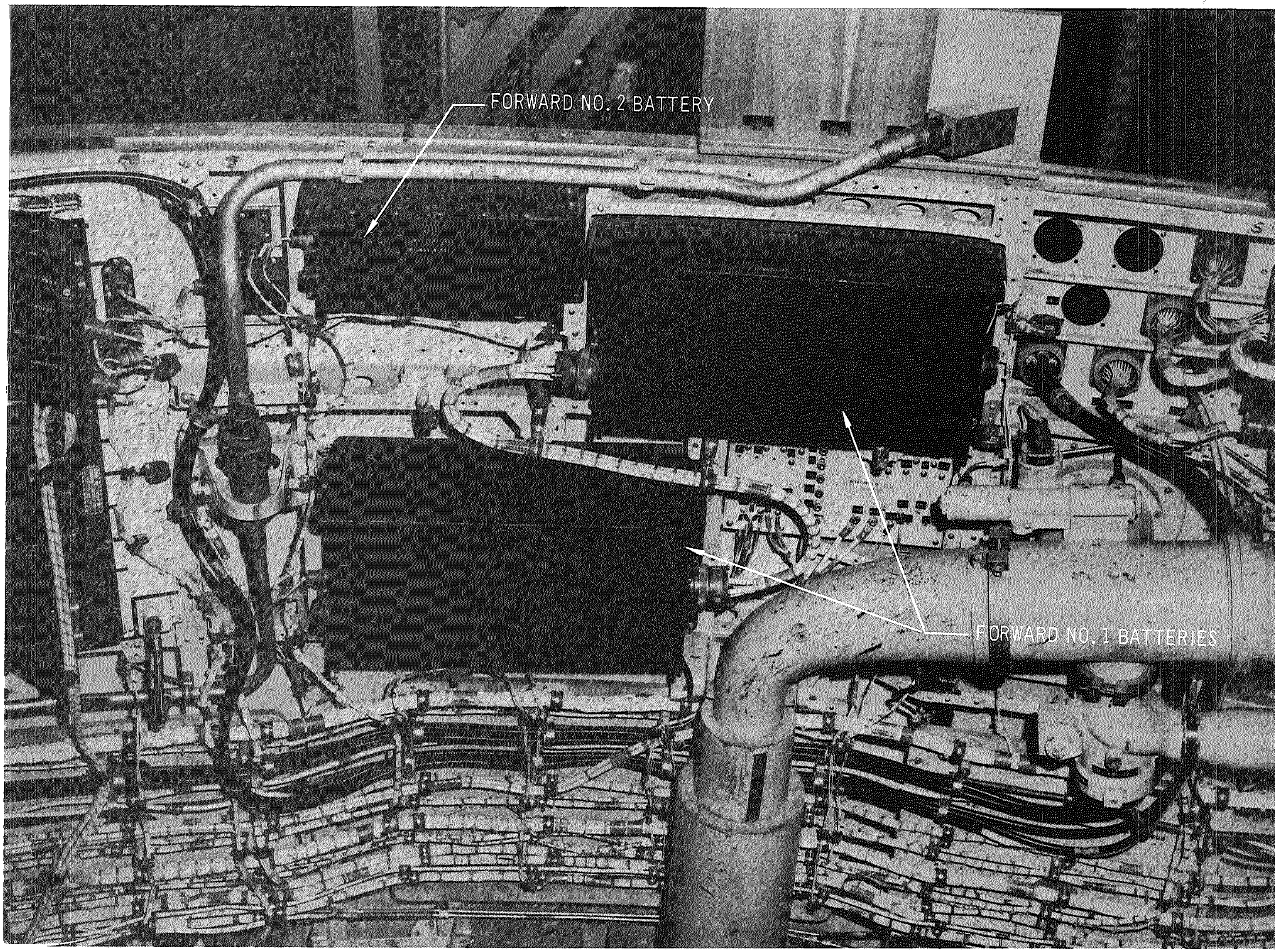


Figure 39. Forward Batteries

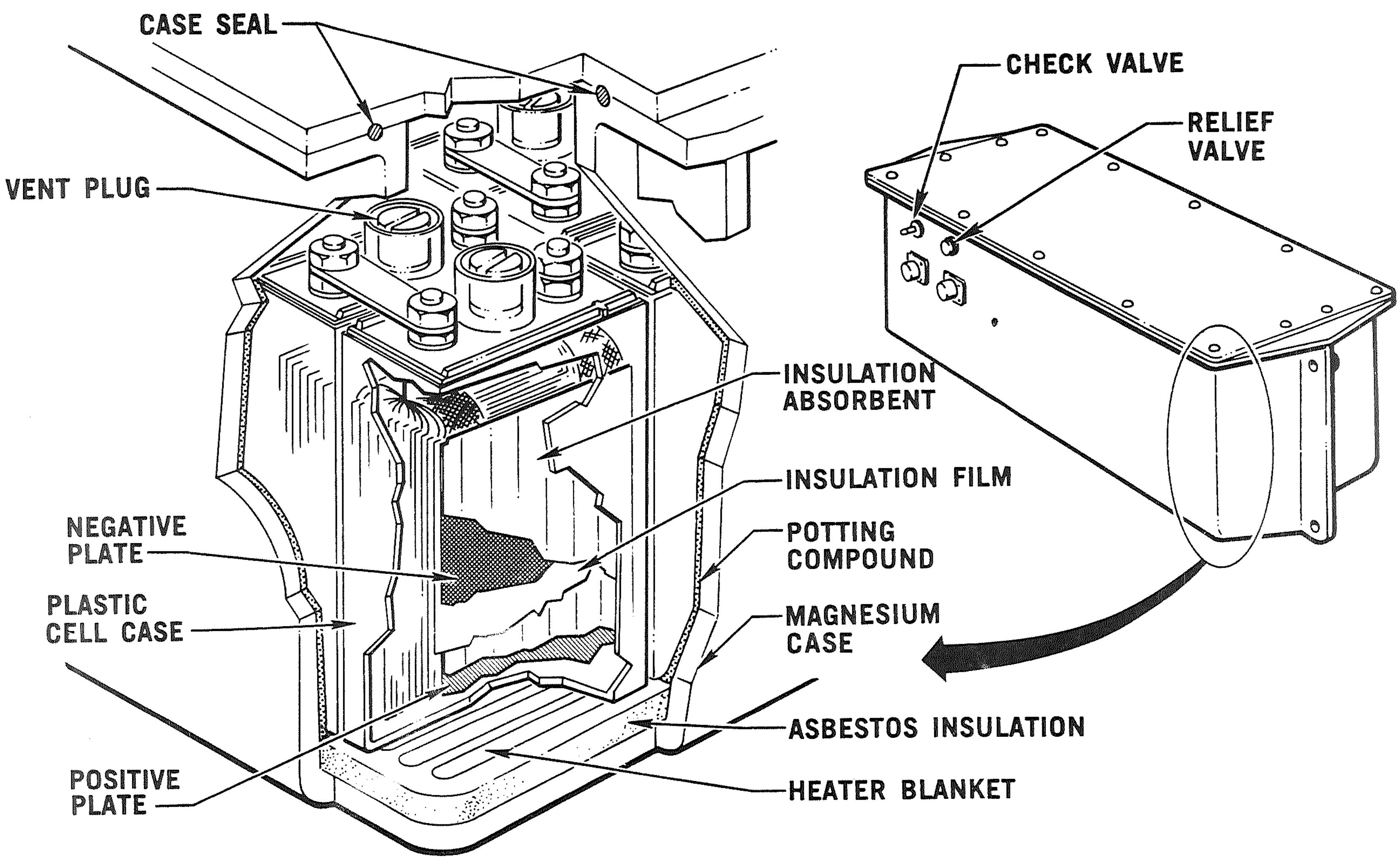


Figure 40. Typical S–IVB Stage Battery

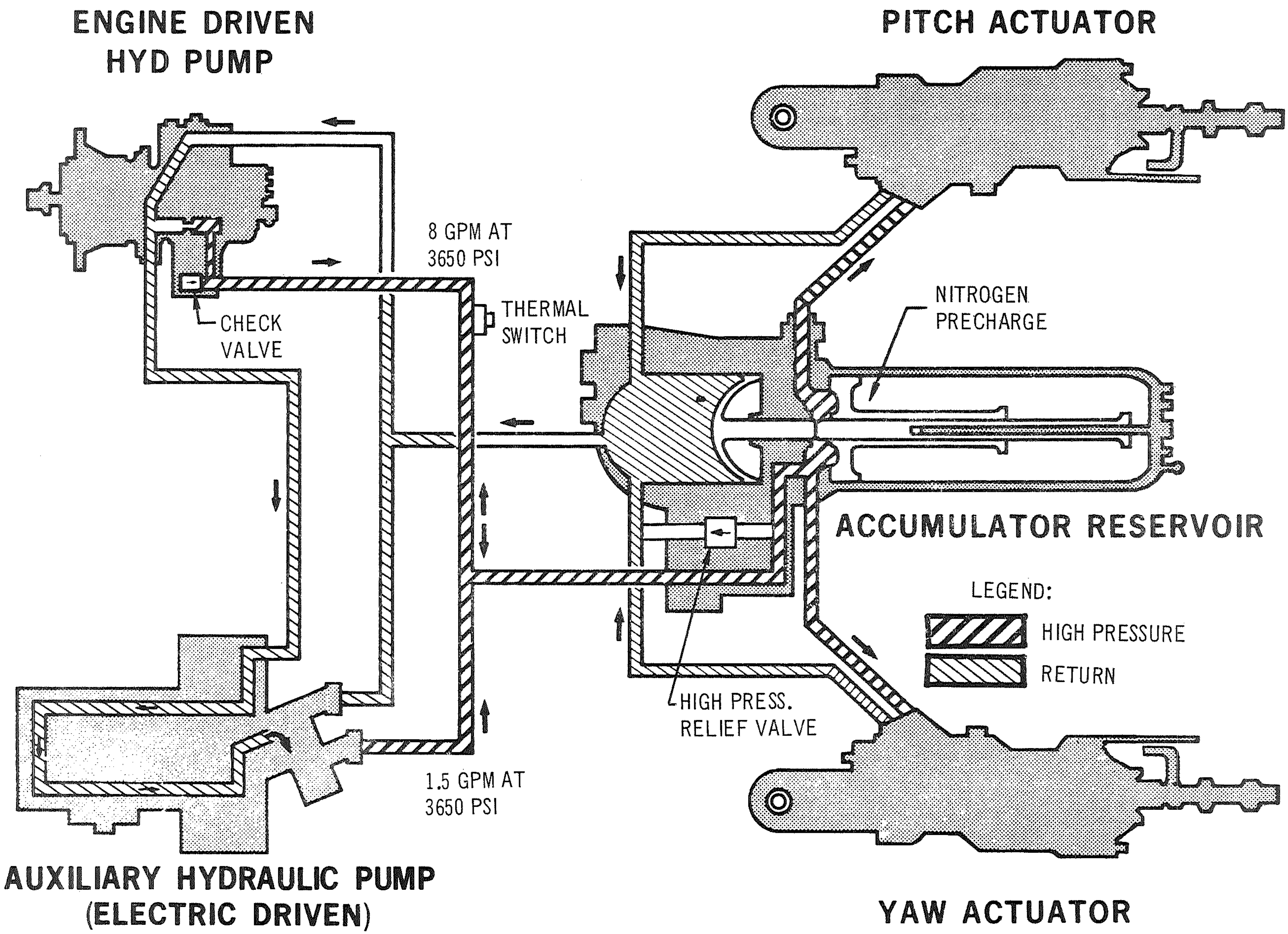


Figure 41. S–IVB Stage Hydraulic System (Sheet 1 of 2)

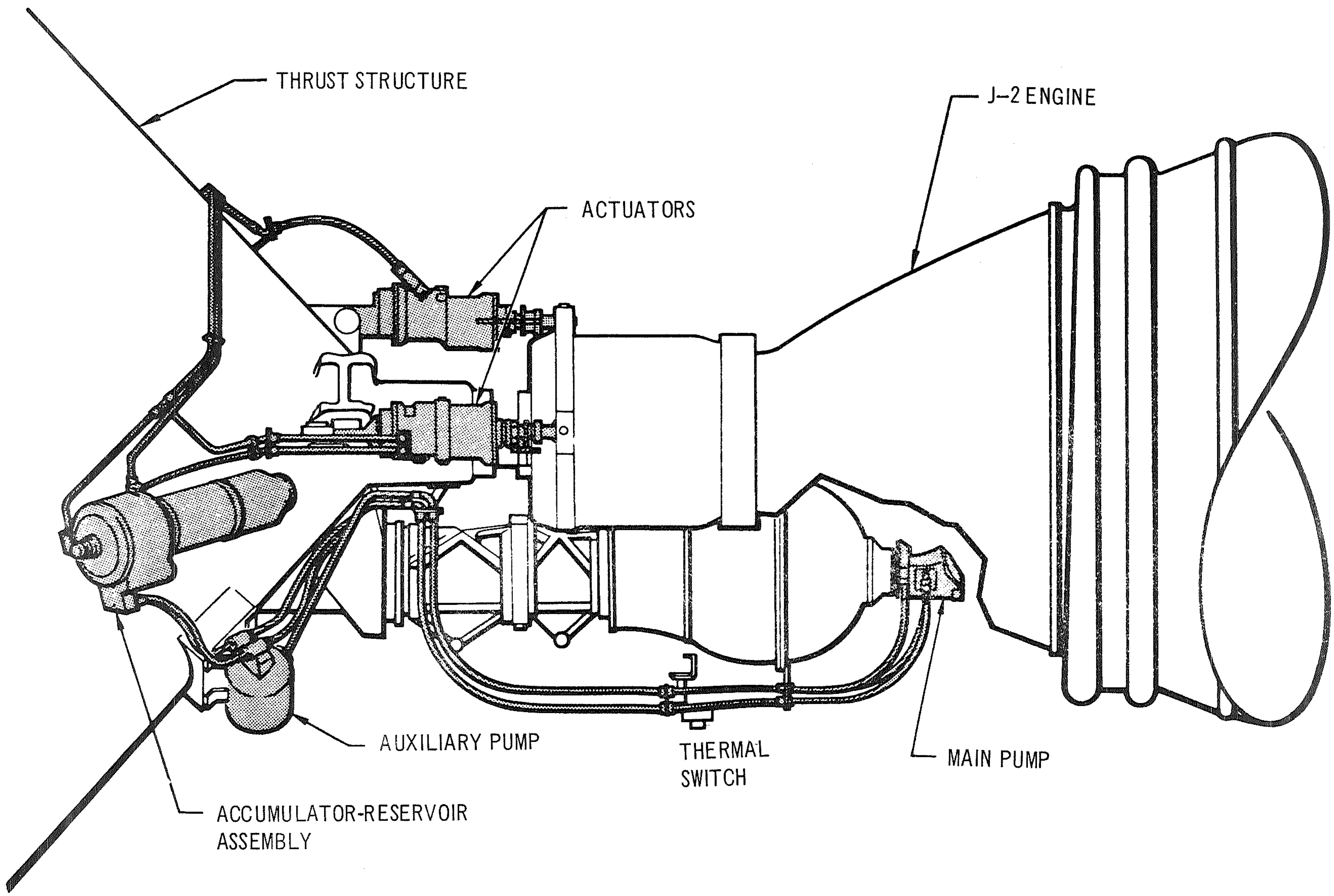


Figure 41. S–IVB Stage Hydraulic System (Sheet 2 of 2)

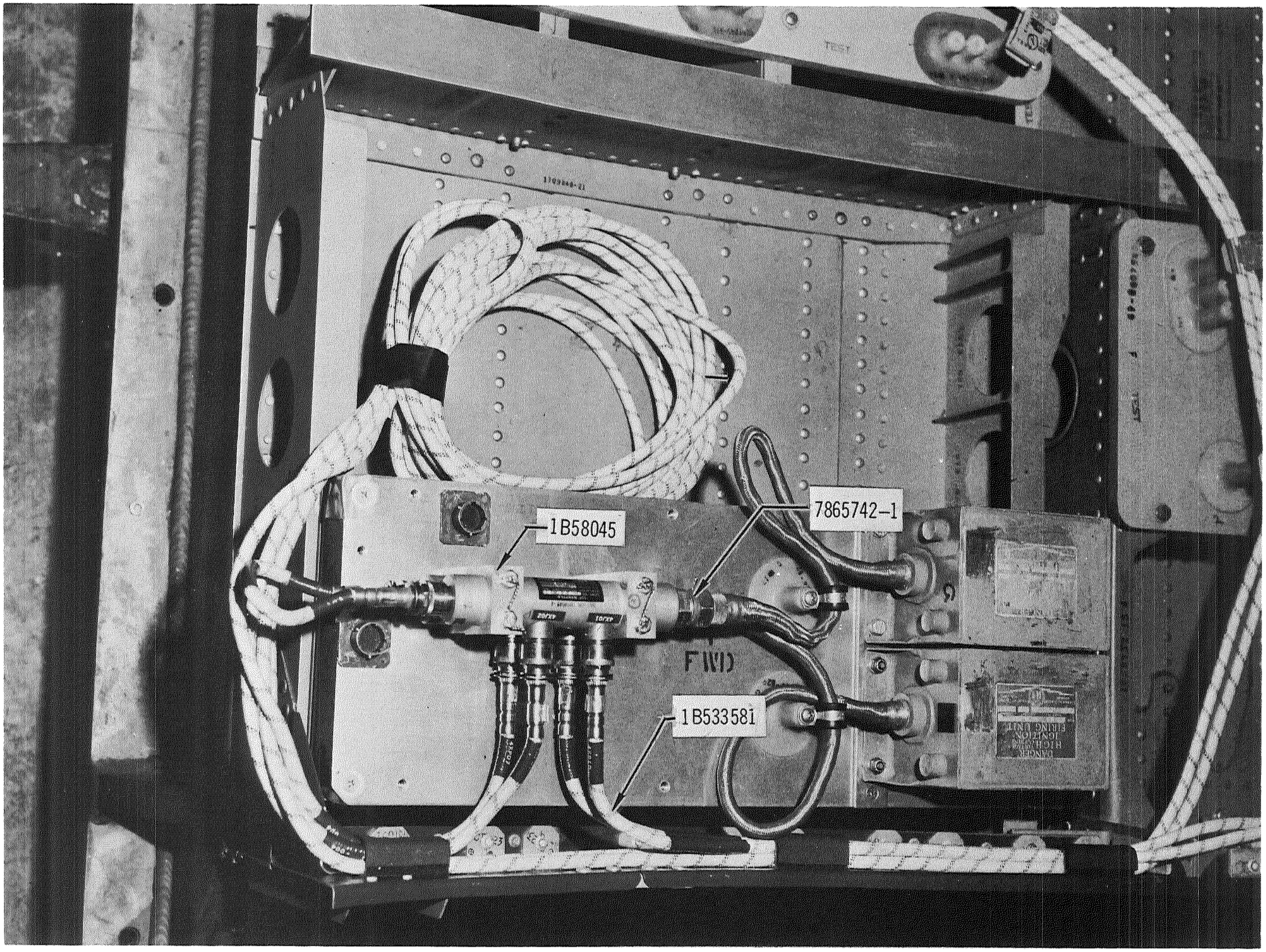


Figure 42. Ordnance System

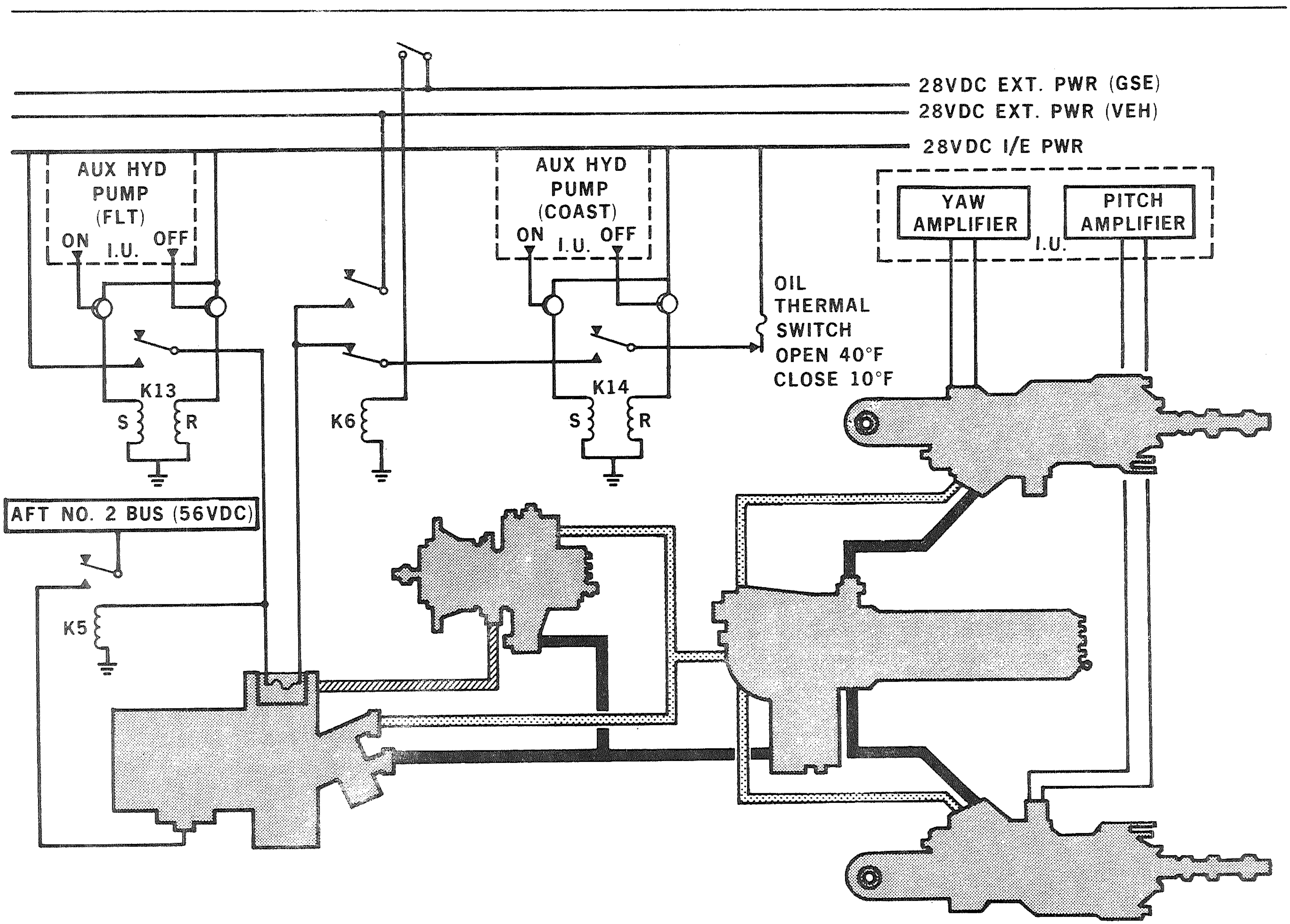


Figure 43. S–IVB Hydraulic System (Electrical Control)

SECTION 4

4. PRESENTATION CONCLUSION - APRIL MEETING

This section deals with the wrap up portion of the presentation. The introduction to the wrap up began with a discussion of "The Nature of the Problem", as related to the product and to Management.

Presented first was: How can you assure successful product performance? The answer offered was: Uncover "soft spots" and take definitive action, and make it clear how Douglas can help you.

Presented then were areas of:

a. Inadequate production design
b. Inadequate manufacturing design

Included in areas of inadequate production design were:

- Lack of understanding of design/mission intent
- Vague and unmeasurable requirements
- "Improvement" changes made to the product without notifying Douglas
- Different interpretation of cleanliness requirements
- Inadequate packaging, handling, storage, and transportation.

Quoted as areas of inadequate product manufacturing were:

- Contamination of the product
- Sealing surface finishes
- Out-of-tolerance dimensions
- Improper torquing
- Inadequate workmanship
- Deficient controls on raw materials.

A series of photographs, figures 44 through 58, were then presented to show examples of many of the deficiencies noted above.

Figure 44.

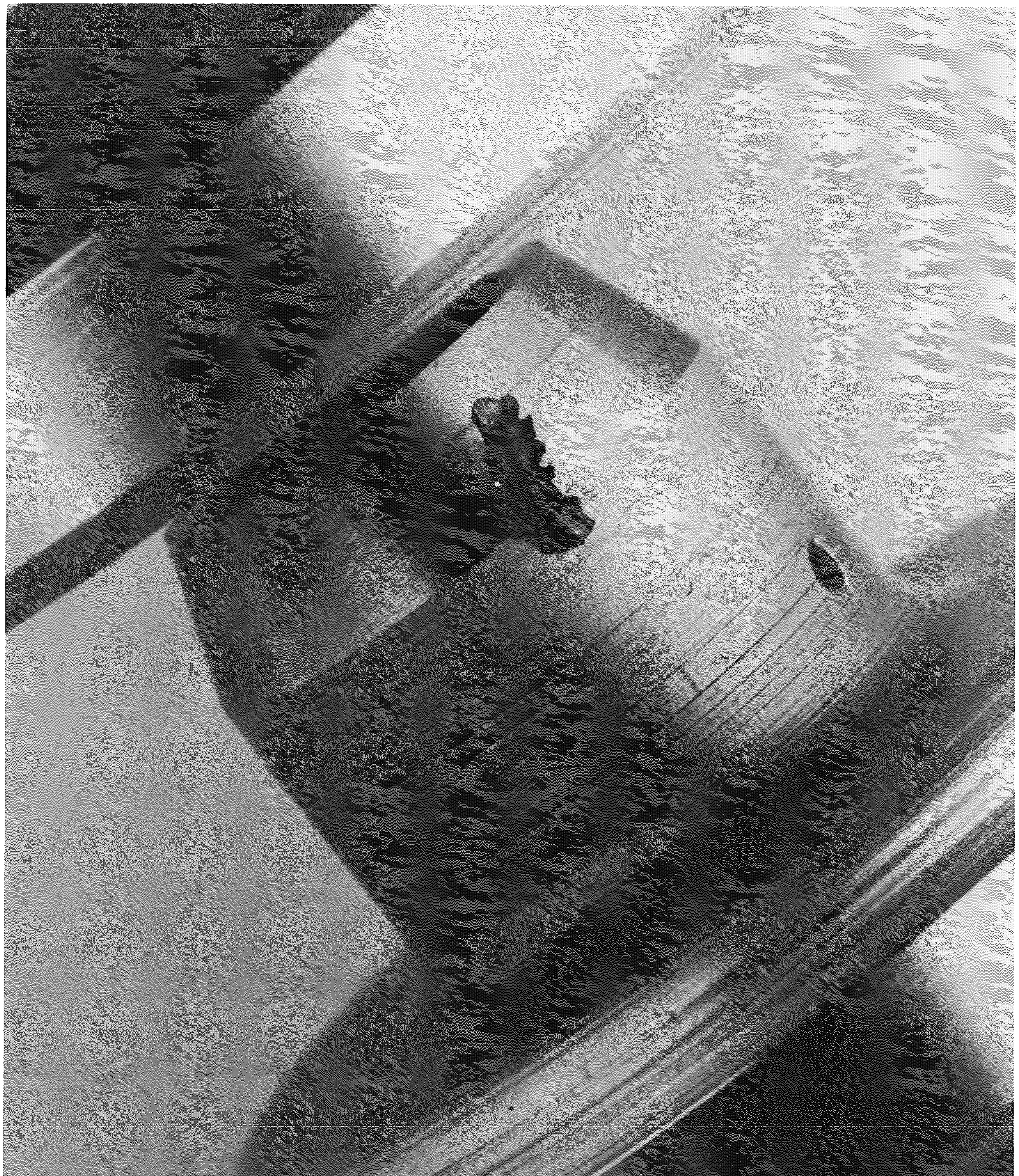


Figure 45.

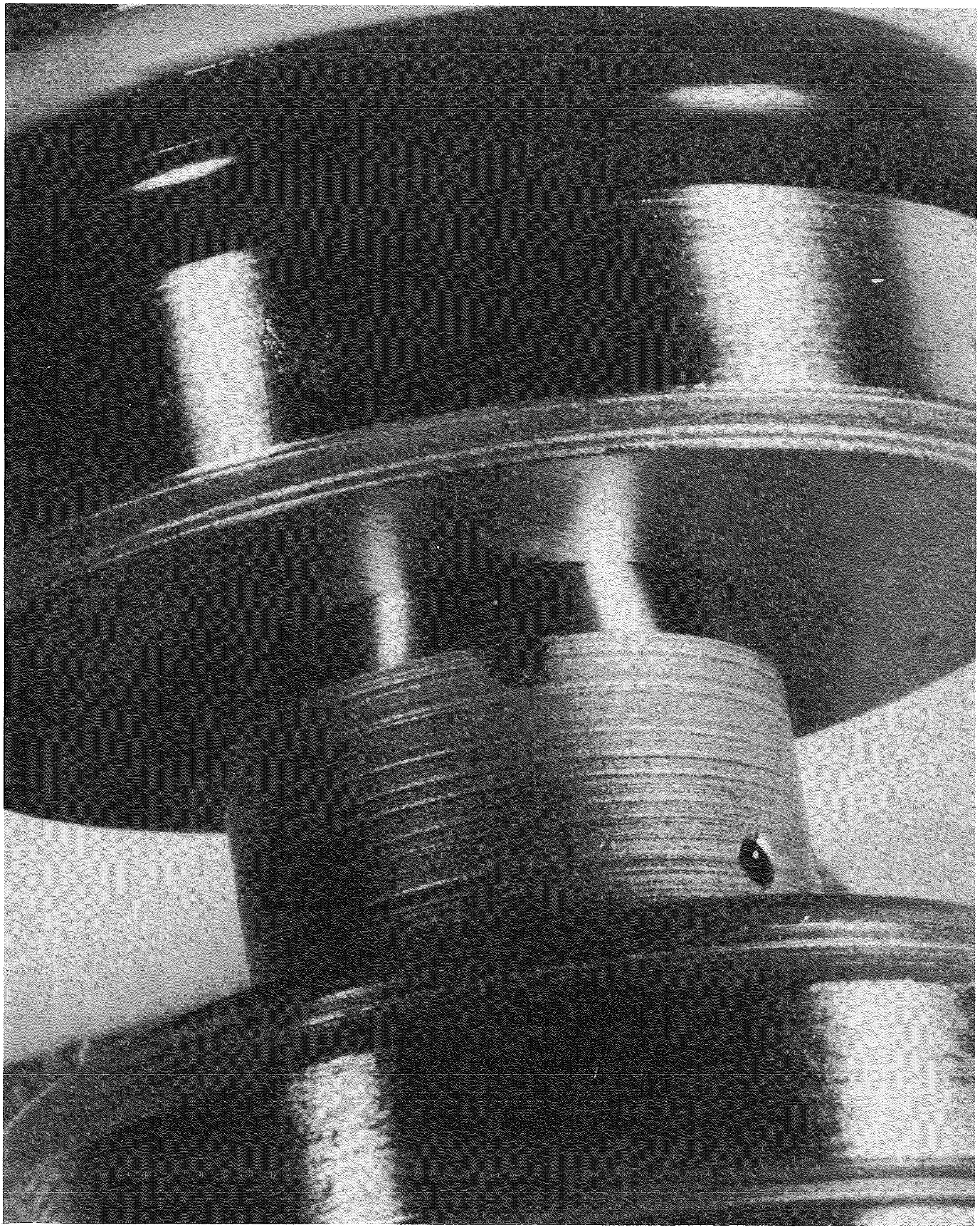


Figure 46.

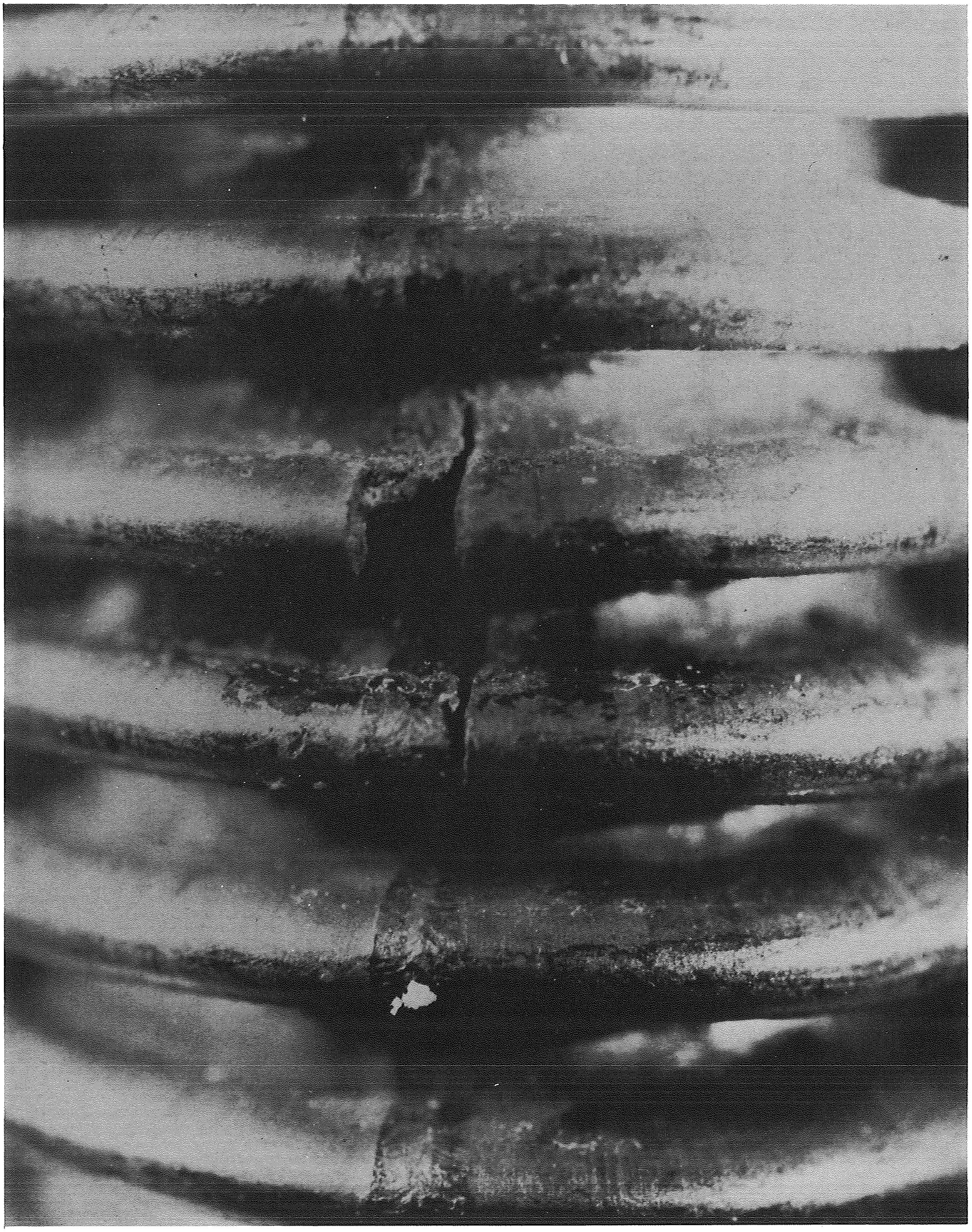


Figure 47.

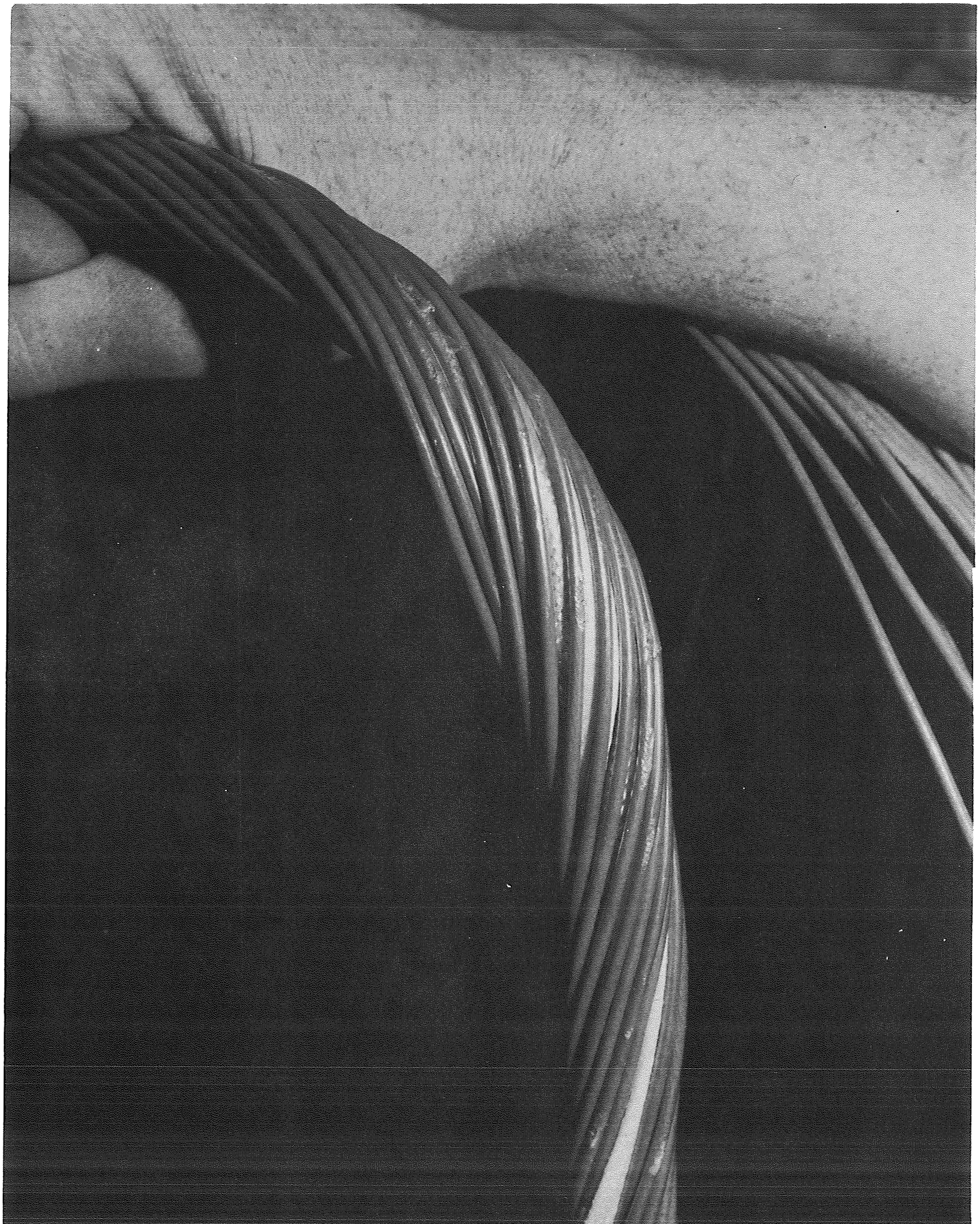


Figure 48.

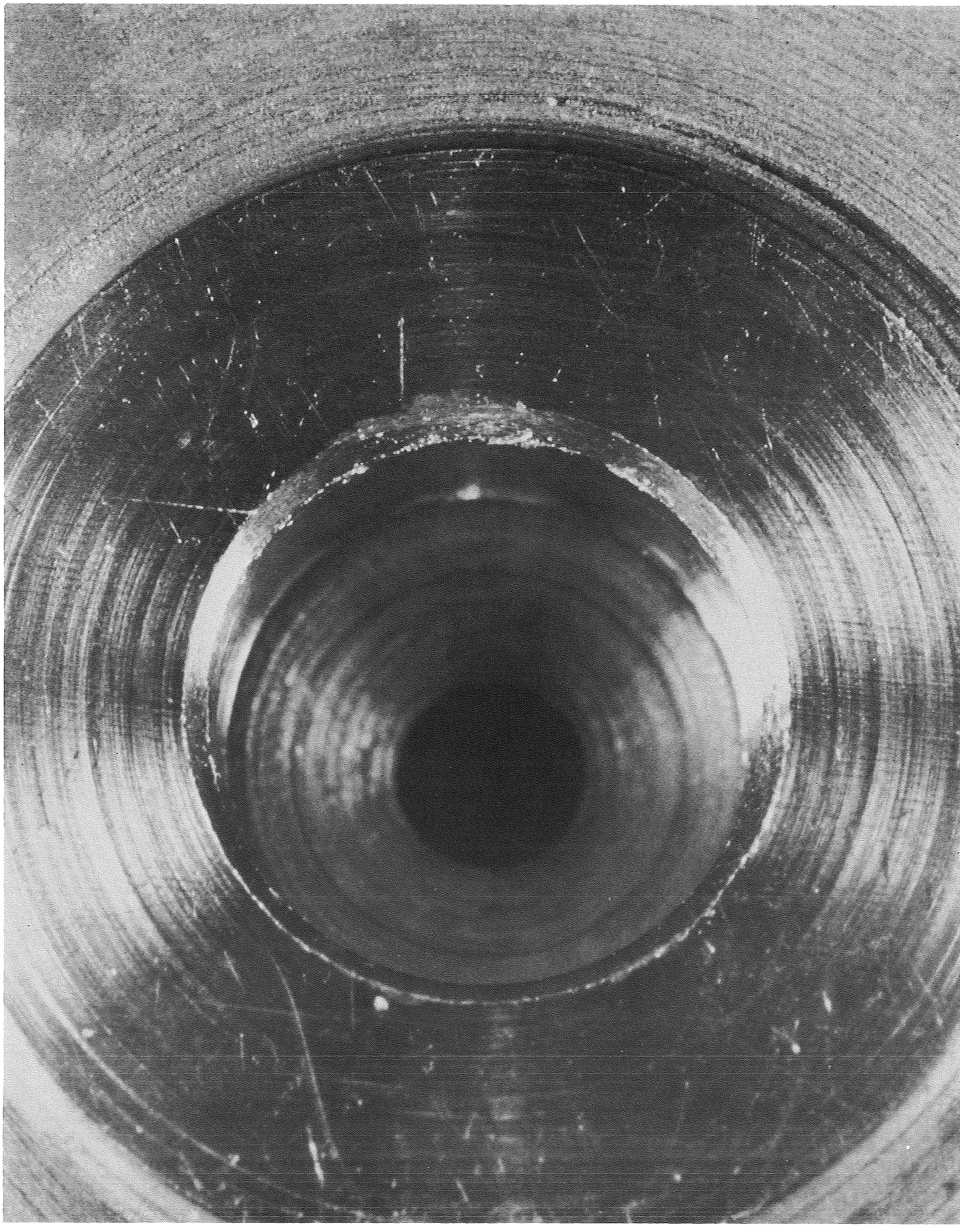


Figure 49.

Figure 50.

Figure 51.

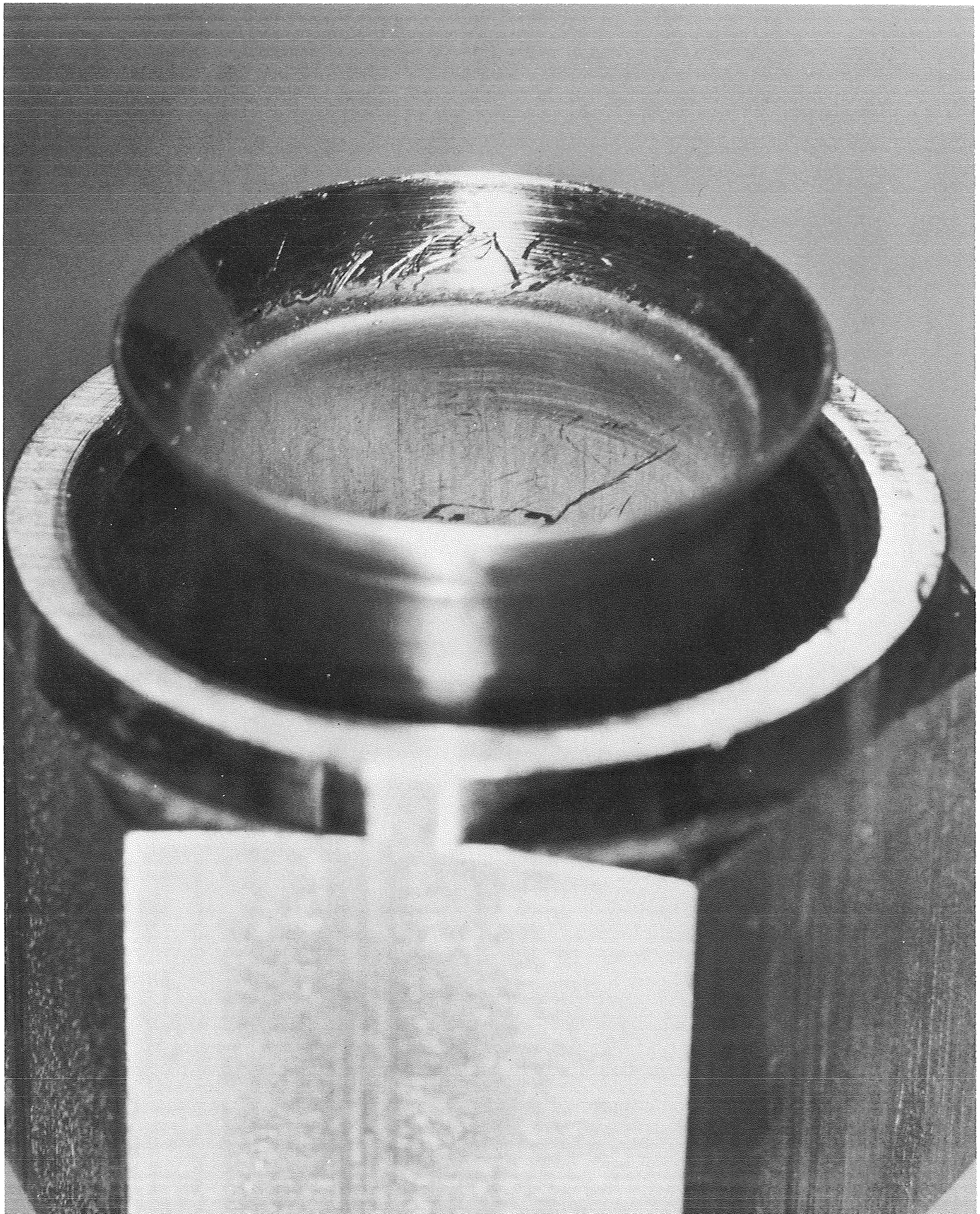


Figure 52.

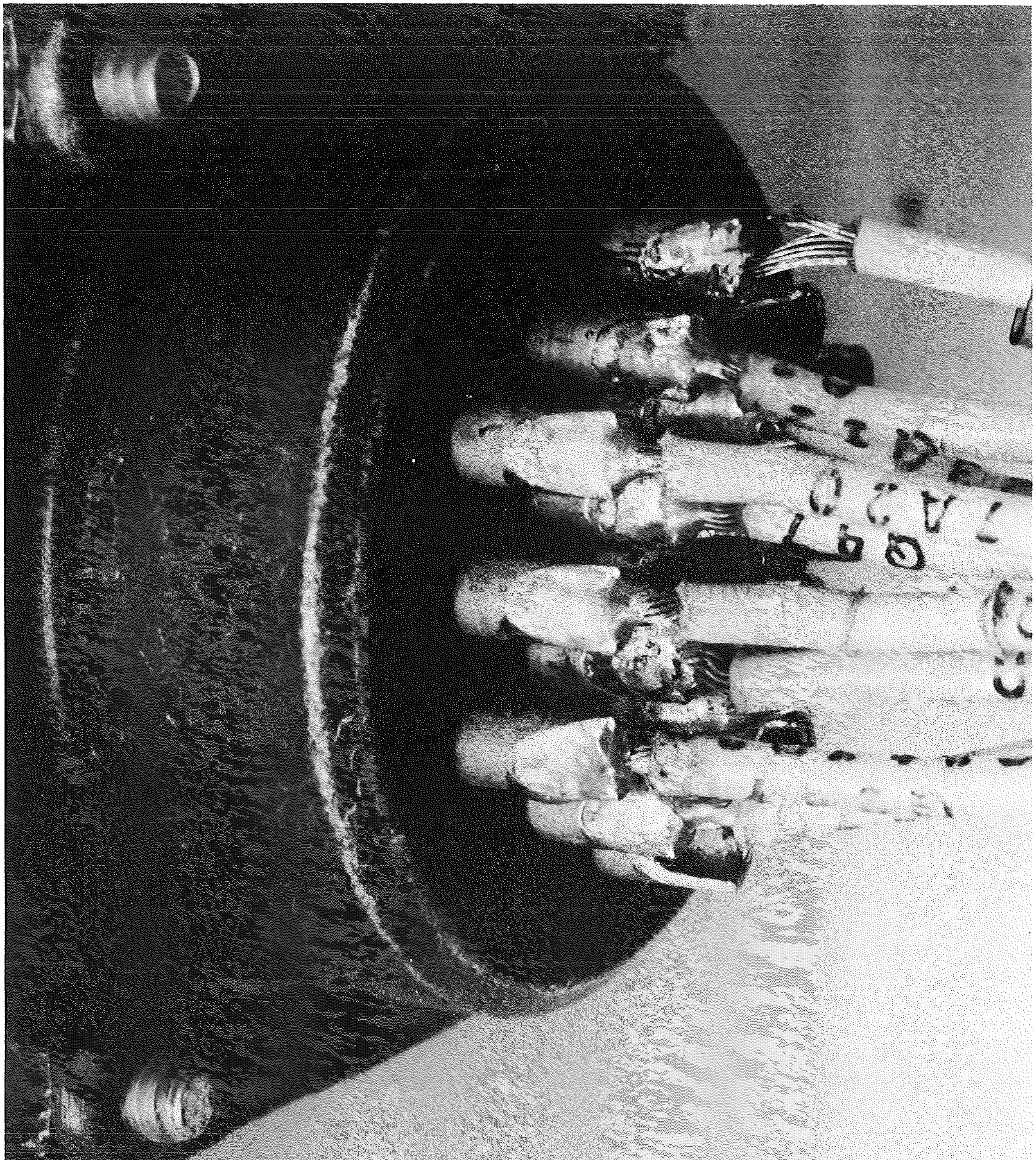


Figure 53.

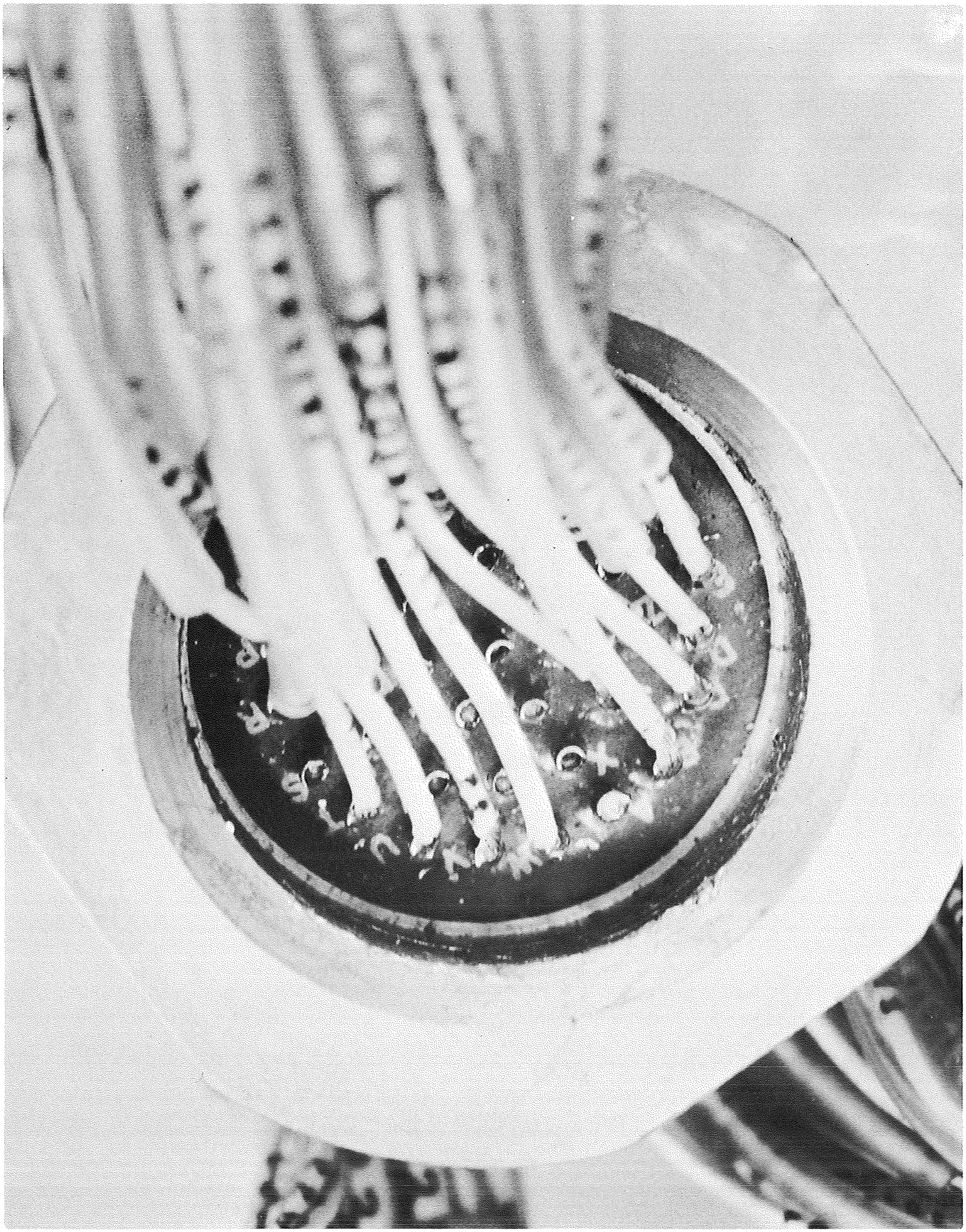


Figure 54.

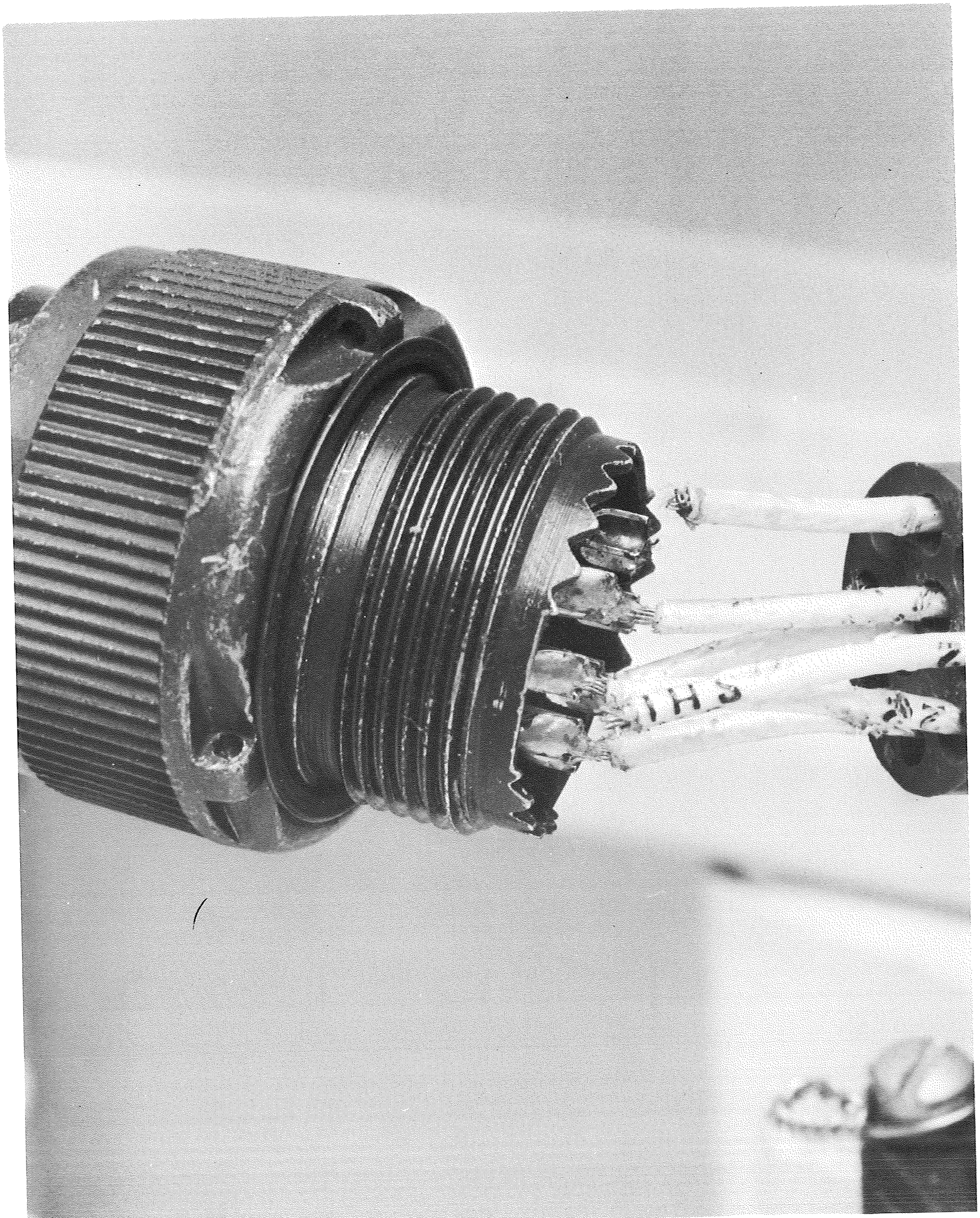


Figure 55.

Figure 56.

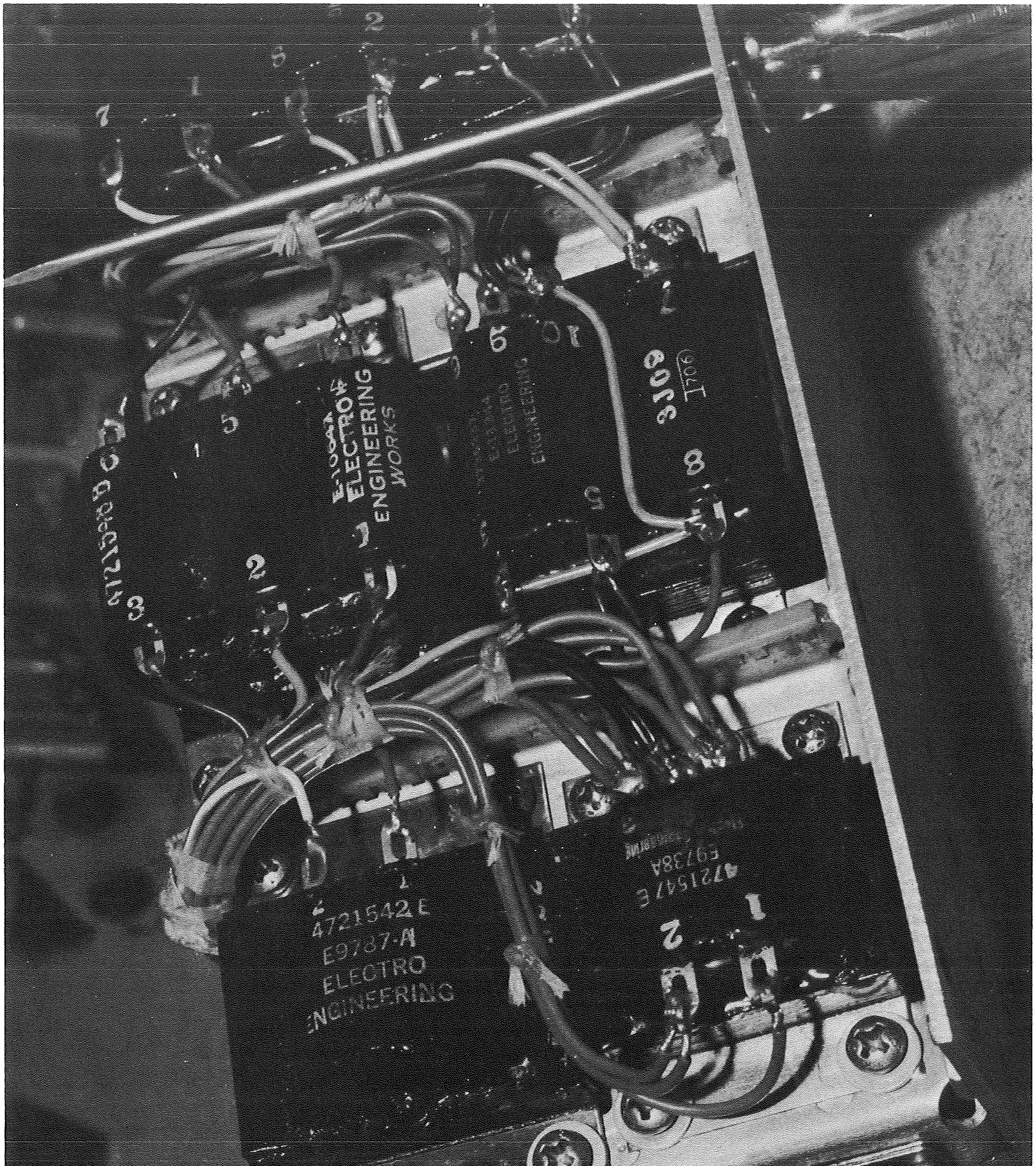


Figure 57.

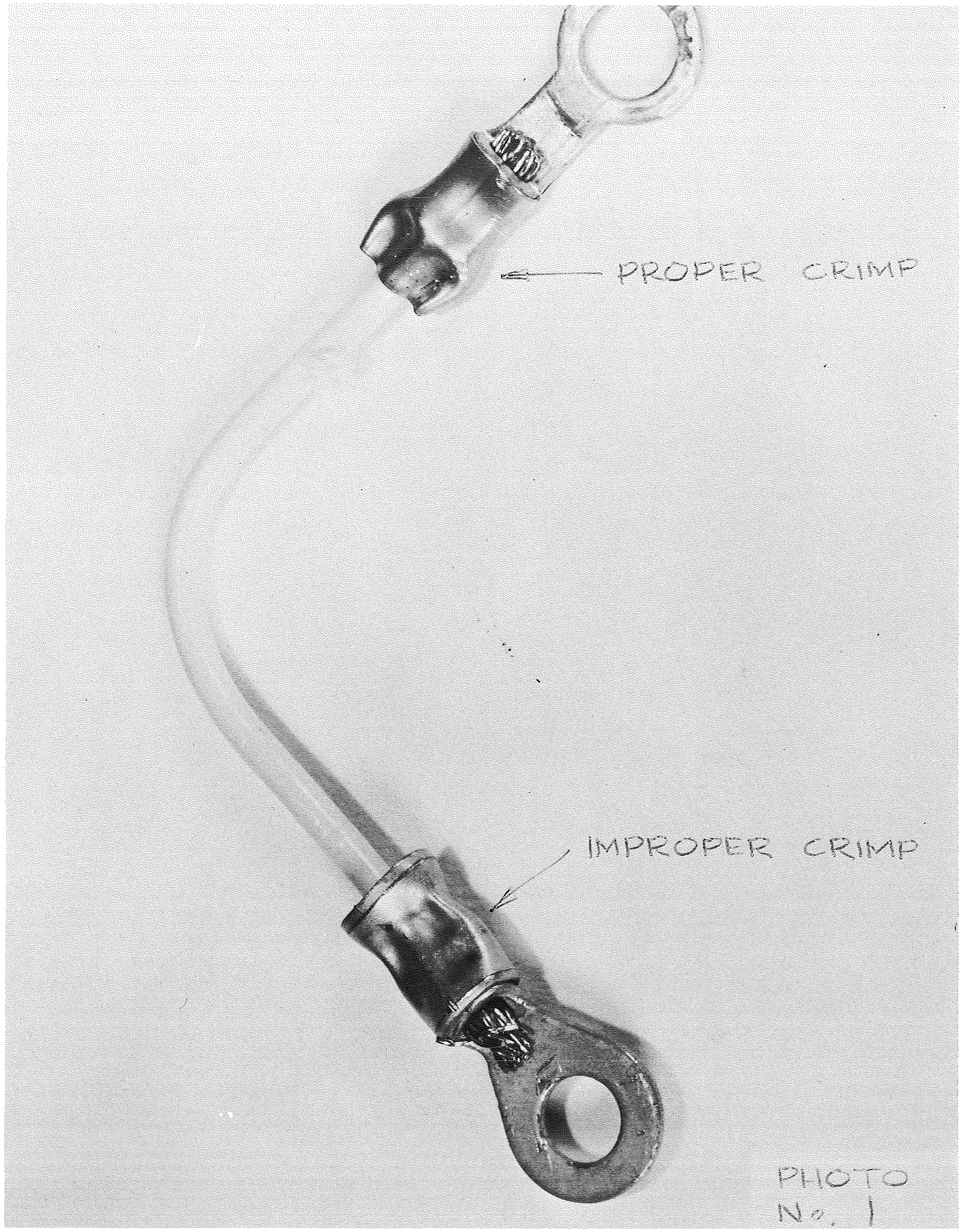


Figure 58.

CONTRACTOR ASSISTANCE

The discussion then turned to: How can the contractor (Douglas) help you? The following procedures were suggested:

a. Use of NASA/Douglas motivation materials

- VIP program material
- Saturn program material
- Published papers
- Douglas presentations and engineering papers

b. Douglas vendor-award program

c. Supplier personnel visits

d. Identification of Douglas "single-point responsible executive"

- E. C. McTavish - Director Procurement - MSSG
- N. A. Doninger - Deputy Director Procurement - MSSG

In closing this portion of the presentation, the vendor's were advised to "take the ball". They were told:

- Your role is vital!
- You can do more than we can, and more effectively.
- This is a two-way street; you can really help us.
- Report back suggestions - REAL problems immediately
- Submit first status report--letter to Douglas by 17 July 1967

Following are the Saturn S-IVB Schedule for 1967, and charts depicting vendor hardware status.

SATURN S-IVB SCHEDULE - 1967

STATIC FIRING AT SACRAMENTO TEST CENTER

S-IVB-209	JUNE 14, 1967
S-IVB-504N	AUGUST 9, 1967
S-IVB-505N	OCTOBER 2, 1967
S-IVB-210N	DECEMBER 20, 1967

LAUNCH FROM KENNEDY SPACE CENTER

S-IVB-501	FOURTH QUARTER 1967
S-IVB-204	FOURTH QUARTER 1967
S-IVB-502	FOURTH QUARTER 1967

HARDWARE STATUS

VENDOR	HARDWARE IDENTIFICATION	P/N	% DEL'D
KINETICS	SWITCH, 300 AMP POWER TRANSFER (MTR DRVN)	IA68085	45
	SWITCH, MTR DRVN, 50 AMP	IA88061	50
UNITED CONTROLS	SWITCH, THERMAL, HYD. SYSTEM TEMP. CONT.	IA74765	30
GENERAL ELECTRIC	RELAY, CRYSTAL CAN, 2 PDT	IB39033	15
	RELAY, GEN PURP, 2 PDT, 2 AMP MAG. LATCH	IB52237	95
POTTER BRUMFIELD	RELAY, GEN PURP, 2 PDT, 2 AMP MAG. LATCH	IB52237	100
BENDIX	SEMICONDUCTOR-DEVICE-DIODE POW RECT. HI REL.	IB54541	0
INTERNATIONAL RESISTOR CORP	RESISTOR, VARIABLE MULTI-TURN WIRE-WOUND	IA59563	100

HARDWARE STATUS

VENDOR	HARDWARE IDENTIFICATION	P/N	% DEL'D
ADEL	MOD., HELIUM FILL APS	IA49996	100
	MOD., LOW PRESS HE APS	IA49998	50
	MOD. PNEU. POWER CONT.	IA58345	70
	MOD., CONT., LH2 PRESS.	IB55200	75
	VALVE, RELIEF, HE CONT.	7851824	100
PNEUDRAULICS	VALVE, RELIEF, HI PRESS.	IA66242	70
CARTER	VALVE, CHECK	IB40824	60
	VALVE, CHECK -HYD VENT PUR.	IB51361	70
STERER	MOD., ACTUATION CONT.	IB66692	5
PUROLATOR PRODUCTS	DISCONNECT HELIUM CONT.	7851823	75

HARDWARE STATUS

VENDOR	HARDWARE IDENTIFICATION	P/N	% DEL'D
LEONARD	MOD., PROPELLANT CONT.	IA49422	60
	VALVE, RELIEF, LOX TANK	IA49590	20
	VALVE, RELIEF, LH2 TANK	IA49591	65
	MOD., CONTINUOUS VENT	IB51753	55
PARKER	VALVE, SWING CHECK, CHILL SYSTEM	IA49964	70
	VALVE, CHECK, HI PRESSURE	IA66245	65
AER-VALCO (CLARY)	VALVE, PROP. TANK SHUTOFF	IA49968	60
	MOD., ACTUATION CONT.	IA49982	100
	VALVE, PNEU., PROP. CONT.	IB59010	60
	MOD., ACTUATION CONT.	IB65292	100
ROYAL INDUSTRIES	MOD., CONT., ENGINE PUMP PURGE	IA58347	70

HARDWARE STATUS

VENDOR	HARDWARE IDENTIFICATION	P/N	% DEL'D
TRW	ENG., AUX. PROPULSION ATT. CONT. 150 LB.	IA39597	60
FAIRCHILD-HILLER	VALVE, FILL & DRAIN	IA48240	65
	VALVE, SHUTOFF, CHILL SYS.	IA49965	65
	MODULE, HELIUM FILL	IA57350	65
	REG., PRESS, HELIUM, APS	IB54601	70
CALMEC	VALVE, VENT & REL., LH2 TANK	IA48257	50
	VALVE, VENT & REL., LOX TANK	IA48312	60
	VALVE, DIR. CONT., LH2 TANK	IA49988	65
	MOD., CONT., LOX TANK PRES.	IB42290	20
	VALVE, SOLE., COLD HE CONT.	IB43660	60
	MOD., COLD HELIUM FILL	IB57781	60
	DISCONNECT, COLD HELIUM	7851844	95
	DISCONNECT, LH2 TANK, PRES.	7851861	65

HARDWARE STATUS

VENDOR	HARDWARE IDENTIFICATION	P/N	% DEL'D
AMERICAN ELECTRONICS	MOTOR-TRANS, SERVO BRDG	IA59320	60
LITTON PRECISION PRODUCTS	POTENTIOMETER, BRIDGE, PROPELLANT UTILIZATION	IA59562	50
SAN FERNANDO ELECTRIC	CAPACITOR, MOTOR TUNING, P. U.	IA59566	90
MAGNETIKA	LH2 BRIDGE TRANSFORMER	IA59568	0
	LOX BRIDGE TRANSFORMER	IA59569	10
MASON ELEC.	SWITCH, STARTER-HYDRAULIC POWER UNIT	IB32647	48
PLANAUTICS	SWITCH, MOTOR DRIVEN	IA88061	100
ELECTRIC COMMUN. INC.	CONTROL RELAY PACKAGE	IB57731	60

HARDWARE STATUS

VENDOR	HARDWARE IDENTIFICATION	P/N	% DEL'D
BELL AEROSPACE	TANK ASSY, APS BLADDER EXPULSION	IB39468	58
PESCO PRODUCTS	PUMP, LH2, AUX., MOTOR DRIVEN, CHILLDOWN	IA49421	68
	PUMP, LOX, AUX., MOTOR DRIVEN, CHILLDOWN	IA49423	58
	PUMP, LH2, AUX., MOTOR DRIVEN, CHILLDOWN	IB37129	100
VICKERS	PUMP, HYD, AUX, MOTOR DR	IA66241	70
MOOG SERVO CONTROLS	ACTUATOR ASSY., HYDRAU.	IA66248	60
STAINLESS STEEL PRODUCTS	DUCT ASSEMBLY, LH2 FEED	IA49320	65
	DUCT ASSY., LOW PRESS, LOX	IA49969	65
AVICA	BELLOWS ASSY., LH2 VENT	IA49986	80
	TEE ASSY., LH2 TANK VENT	IA49987	55

HARDWARE STATUS

VENDOR	HARDWARE IDENTIFICATION	P/N	% DEL'D
HONEYWELL	PROBE, LOX MASS	IA48430	65
	PROBE, LH2 MASS	IA48431	68
THIOKOL	MOTOR, ULLAGE ROCKET	IA81960	40

HARDWARE STATUS

VENDOR	HARDWARE IDENTIFICATION	P/N	% DEL'D
SIGNET SCIENTIFIC	OVEN, COMPONENT, PROP. UTILIZATION	IA59564	80
GENERAL LAB ASSOCIATES	ENGINE IGNITION SYSTEM, HELIUM HEATER	IB59968	100
BABCOCK	RELAY, GEN. PURP., 10 AMP	IA67747	100
	RELAY, 2 PDT MAG. LATCH, 10 AMP	IB42260	100
	RELAY, GEN PURP, 10 AMP	IB58584	98
	RELAY, 2 PDT MAG LATCH, 10 AMP	IB58777	50

HARDWARE STATUS

VENDOR	HARDWARE IDENTIFICATION	P/N	% DEL'D
EXPLOSIVE TECHNOLOGY	TEE ASSY., EXPLOSIVE CONFINED DETON. FUSE	1B53585	100
AIRTEK	TANK, COMP GAS, CONT HE	1A48857	65
	SPHERE, STORAGE - HE	1A49963	55
	TANK, STORAGE, HE PROP TANK REPRESS	1A49990	80
MENASCO	SPHERE, STOR, HE LOX TANK PRESS	1A48858	58
	TANK, COMP GAS, COLD HE	1A49991	60
	TANK, COMP GAS, AIR	1B55725	65
BERTEA	ACCUMULATOR RESERVOIR	1B29319	60

HARDWARE STATUS

VENDOR	HARDWARE IDENTIFICATION	P/N	% DEL'D
FREBANK	SWITCH, PRESS, PUMP PURGE REGULATOR BACKUP	IA67002	95
	SWITCH, PRESS, LH2 TANK REPRESS. CONTROL	IA67005	95
	SWITCH, MED PRESS, HE CONT	7851830	95
	SWITCH, LOW PRESS LOX	7851847	95
	SWITCH, LH2 TANK FLIGHT CONTROL	7851860	95
HYDRA-ELECTRIC	SWITCH, PRESSURE	IB52623	75
CONSOLIDATED CONTROLS	SWITCH, PRESS, HI PERF.	IB52624	75
McCORMICK-SELPH	DETONATOR, ELEC. EXPLODING BRIDGEWIRE	7865742-1	100
ENSIGN BICKFORD	FUSE ASSY., EXPLOSIVE, CONFINED DETON. FUSE	IB53581	100

HARDWARE STATUS

VENDOR	HARDWARE IDENTIFICATION	P/N	% DEL'D
EAGLE-PITCHER	BATTERY, WET, FOR. & AFT NO. 1 BUS	IA59471	38
	BATTERY, WET, FORW. NO. 2 BUS	IA68316	38
	BATTERY, WET, AFT NO. 1 BUS	IA68317	60
	BATTERY, WET, FORW. NO. 1 BUS	IA83468	100
	BATTERY, WET, FORW. NO. 2 BUS	IA83469	50
	BATTERY, WET, AFT NO. 1 BUS	IA83470	50
	BATTERY, WET, AFT NO. 2 BUS	IA93471	50
AIRCRAFT POROUS MEDIA	FILTER ELEMENT, MAIN SYS.	IA66244	90
	FILTER, COLD HELIUM	IB43659	75
SEALOL	BELLOWS ASSEMBLY	IA67911	65
WESTERN FILTER	FILTER, INLINE, HE, N_2O_4 & MMH 25 MICRON	IB55934	60

HARDWARE STATUS

VENDOR	HARDWARE IDENTIFICATION	P/N	% DEL'D
TECH INSTR CORP	POTENTIOMETER	IA59562	40
HI SHEAR	NUT FRANGIBLE	IA72620	0
GIANNINI CONTROLS	TRANSDUCER PRESS. LH2	IB43320	16
	TRANSDUCER PRESS. LOX	IB43324	21
RANDALL	VALVE	IB51184	100
	VALVE	IB53718	60
LINK ORDN.	PYROGEN INITIATOR CDF	IB53584	TBD
AEROQUIP-MARMAN	BELLOWS FILL & DRAIN	IA49971	60
	LH2 FILL BELLOWS	IA49979	0
	LH2 CHILLDOWN RETURN	IA87741	TBD
ANACONDA METAL HOSE	HOSE ASSY. METAL	IA48852	100
	HOSE ASSY. METAL	IA48853	100

HARDWARE STATUS

VENDOR	HARDWARE IDENTIFICATION	P/N	% DEL'D
DUNBAR KAPPLE	BURNER LH2	1B59005	60
	LOX FEED LINE BURNER	1B59009	60
	BURNER LH2	1B65206	60
FLEX. METAL HOSE	HOSE ASSY. METAL	1A48850	38
	HOSE ASSY. METAL	1A48852	8
	HOSE ASSY. METAL	1A48853	TBD

PRODUCT QUALITY CONTROL

Next discussed was quality control of the product, which was termed "inadequate" because of inadequate inspection/test procedures, ineffective monitoring of processes, and inadequate material review. The last, inadequate material review, included inadequate disposition of nonconforming materials, incomplete failure analyses to determine true cause/causes of failure, inadequate corrective action and follow-up, and inability to detect the relationship of series of "minor" problems.

Inadequate control of sub-tier supplier products was then discussed, i.e., sub-tier awareness, incomplete definition of requirements, and inadequate control of product.

The last area of inadequacy discussed was inadequate management systems and procedures, including the following:

a. Communications -- Misunderstanding of intent between:

  - Douglas and suppliers
  - Suppliers internal departments
  - Suppliers and sub-tier suppliers

b. Audits -- Insufficient to evaluate effectiveness of procedures

c. Changes -- Inadequate control on all documents

d. Product deficiencies -- Lack of visibility

Vendor Awareness

Vendor Awareness, the meat of the presentation, became the next, and most important segment of the presentation. The discussion began with suggested means of: How to uncover soft spots. Suggested were:

a. Prepare a spot-check audit plan

b. Implement the plan to the fullest measure

c. Prepare lists of discrepancies for follow-up action

d. Prepare and list recommendations

The following charts present the preventive and remedial actions recommended, in relation to a through d above.

VENDOR AWARENESS

I. PREPARE A PRODUCT AUDIT PLAN

A. LIST AUDIT OBJECTIVES -- TRACE A DELIVERED END ITEM FROM PURCHASE ORDER RECEIPT THROUGH PRODUCT DELIVERY

a) TO UNCOVER SOFT SPOTS

b) TO DETECT SYSTEM/PROCEDURE DISCREPANCIES

c) TO DETECT IMPLEMENTATION DISCREPANCIES

B. WHO COULD PARTICIPATE? -- A TEAM CHAIRED BY AN OBJECTIVE INDIVIDUAL (ONE WHO IS NOT RESPONSIBLE FOR DESIGN, MANUFACTURE, OR PROCUREMENT)

C. WHEN SHOULD IT BE COMPLETED? -- APPROXIMATELY 30 DAYS

VENDOR AWARENESS

D. WHAT TASKS COULD BE INCLUDED?

- a) DAC PURCHASE ORDER REQUIREMENTS -- COMPARE TO SUPPLIER DESIGN REQUIREMENTS
- b) SUPPLIER DESIGN REQUIREMENTS
  1. COMPARE DESIGN REQUIREMENTS TO MANUFACTURING AND QUALITY REQUIREMENTS
  2. COMPARE DESIGN REQUIREMENTS TO PROCUREMENT REQUIREMENTS
- c) SUPPLIER PROCUREMENT REQUIREMENTS -- COMPARE TO SUBTIER SUBMITTALS
- d) SUBTIER REQUIREMENTS
- e) MANUFACTURING/QUALITY REQUIREMENTS -- COMPARE TO IMPLEMENTATION

E. IMPLEMENT AUDIT

VENDOR AWARENESS

F. LIST DISCREPANCIES

- a) PRODUCT
- b) SYSTEMS/PROCEDURES
- c) IMPLEMENTATION/DISCIPLINE

G. LIST RECOMMENDATIONS

- a) PRODUCT
  1. DELIVERED
  2. IN-PROCESS
  3. FUTURE FOLLOW-ON
- b) SYSTEMS/PROCEDURES
- c) IMPLEMENTATION/DISCIPLINE

SECTION 5

5. JUNE PRESENTATION

This portion of the report presents the data used at the follow-on Vendor Awareness meeting held during June 1967.

5.1 Vendors Flight Critical Items

Following is a breakdown by category of vendor flight critical and hazardous items discussed and a brief description of the function and criticality of each component.

5.1.1 Propulsion System

A description of this system and its function is given in paragraph 3.1. The following components were discussed.

- D. K. MANUFACTURING CO.

O_2/H_2 Burner, Duct, Vacuum Jacketed, LOX, Part Number 1B59009-501 (Figure 59)

This duct is installed between the LOX control valve (1B59010) and the O_2/H_2 burner LOX inlet. The duct runs from the bottom of the LOX tank, parallel to the thrust structure, until it reaches the burner.

The function of the duct is to transfer LOX from the LOX tank outlet (through the LOX control valve) to the O_2/H_2 burner.

Failure of the duct (leakage) during operation of the O_2/H_2 burner, either during static test or inflight, could cause

a. Decreased performance of the O_2/H_2 burner which would result in failure to properly pressurize the vehicle tanks and failure to complete the mission.

b. Explosion hazard would also exist, which could result in destruction of the vehicle.

O_2/H_2 Burner, Duct, Vacuum Jacketed, LH_2 Lower, Part Number 1B59005-501

This duct is installed between the fuel control valve (1B59010) and the O_2/H_2 burner fuel inlet. Runs from near the bottom of the fuel tank on the outside skin of the vehicle, through the aft skirt, and parallel to the thrust structure until it reaches the burner. See figure 59.

The function of this duct is to transfer fuel from the fuel control valve (1B59010) to the O_2/H_2 burner.

Failure of the duct (leakage) during operation of the O_2/H_2 burner, either during static test or inflight, could cause

a. Decreased performance of the O_2/H_2 burner which would result in failure to properly pressurize the vehicle tanks, and failure to complete the mission.

b. An explosion hazard would also exist, which could result in destruction of the vehicle.

O_2/H_2 Burner, Duct, Vacuum Jacketed, LH_2 Tank, Part Number 1B65206-503

This duct is installed between the fuel tank outlet and the fuel control valve (1B59010), located near the bottom of the fuel tank on the outside skin of the vehicle. See figure 60.

The function of the duct is to transfer fuel from the fuel tank outlet to the fuel control valve (1B59010).

Since this duct is located at the fuel tank outlet with no shutoff valve between it and the tank, it will be full of fuel at all times during the mission. Failure of the duct (leakage) at any time during a static test or inflight would cause an explosive hazard which could result in destruction of the vehicle. In addition, failure during operation of the O_2/H_2 burner, either during static test or inflight, could result in decreased performance of the O_2/H_2 burner. This would result in failure to properly pressurize the vehicle tanks, and failure to complete the mission.

- ANACONDA METAL HOSE

<u>Hose Assy, Metal, Part Number 1A48850-507 (Figure 61)</u>

Component is used between umbilical piping run on LOX dome and aft skirt to provide flexibility for rigid piping used in the pneumatic control system.

Failure of this hose, while on the ground, would cause a delay in launch, due to loss of ambient helium gas, which is used to actuate various valves during countdown.

Failure of this hose during flight would result in mission loss, due to the loss of helium used to actuate various valves.

<u>Hose Assy., Metal, Part Number 1A48852-507 (Figure 61)</u>

This component is located between the umbilical piping run on the LOX dome and aft skirt, to provide flexibility for rigid piping used in the cold helium pressurization system.

Failure of this hose, while on the ground, would cause a launch delay, due to loss of helium which is used to pressurize the LOX tank.

Failure of this hose during flight would result in mission loss, due to the inability to pressurize the LOX tank.

<u>Hose Assy., Metal, Part Number 1A48852-509 (Figure 61)</u>

This component is located at the aft end of forward skirt, to provide flexibility for rigid piping used in the cold helium pressurization system.

Failure of this hose, while on the ground, would cause a launch delay, due to loss of helium which is used to pressurize the LOX tank.

Failure of this hose during flight would result in mission loss, due to the inability to pressurize the LOX tank.

Hose Assy., Metal, Part Number 1A48853-505 (Figure 61)

This part is used between the umbilical piping run on the LOX dome and aft skirt, to provide flexibility for rigid piping used in the LH_2 tank pre-pressurization system.

Failure of this hose, while on the ground, prior to or during the prepressurization operation, would cause a launch delay due to inability to pressurize the LH_2 tank.

Failure after pressurization operation or during flight would not affect mission, since this hose is located downstream of a check valve.

- AEROQUIP-MARMAN

Bellows Fill and Drain, Part Number 1A49971 (Figure 62)

This component is located in the aft skirt between the fill and drain valve and the LOX tank.

This component transfers LOX into the tank during fill and maintains integrity of LOX tank after fill when fill and drain valve is closed. Bellows flexibility is required to compensate for manufacturing tolerances and thermal contraction.

Bellows failure would cause loss of oxidizer propellant into the aft skirt and interstage with a loaded tank and spewing of LOX into the aft skirt during tank loading. Failure would be hazardous to stage integrity.

LH_2 Fill Bellows, Part Number 1A49979 (Figure 63)

This component is located in the aft skirt area between the fill disconnect and the fill and drain valve, to provide flexibility to compensate for manufacturing tolerances and thermal contraction.

Failure of the bellows would cause hydrogen to spew into the aft skirt area during fill. Since this bellows is downstream of the fill and drain valve, it would have no effect on the flight mission.

• RANDALL

Vent Relief Valve, Part Number 1B53817 (Figure 69)

This valve is installed in the Ambient Helium Fill and Purge System, two in the Saturn IB and four in the Saturn V. The valve is used during ground checkout operations to purge, with ambient helium, the actuation control module, LOX tank vent relief valve, and the vent system forward of the fuel tank.

Failure of the valve during ground operations would circumvent loading of the stages. The valve is capped following purging, and is not used in flight.

5.1.2 Electrical/Electronic System

The following electrical/electronic components were discussed.

- GIANNINI CONTROLS

Transducer Press. LOX, Part Number 1B43324-601 (Figure 64)

Measurements D179 and D180 are mounted on vibration isolators on the thrust structure to measure oxidizer tank ullage pressure for determination of adequate pressure for engine operation.

Failure of one EDS pressure measurement (D179 or D180) would result in a loss of data and would have a minimal effect on mission or ground operations. The current design is such that one EDS measurement D179 is redundant to the other measurement D180. Additionally, oxidizer pump inlet pressure, measurement D3 provides essentially the same datum which can be used as additional information. These pressure measurements are not the means by which an automatic or manual abort sequence for the safety of the Apollo crew is initiated. This is accomplished via mainstage pressure switch voting logic or by an angular overrate condition initiating an automatic abort sequence during boosting phases of the S-IVB stage. The EDS pressure transducers are utilized for monitoring purposes only.

Transducer Press. LH_2, Part Number 1B43320-601 (Figure 64)

Measurements D177 and D178 are mounted on vibration isolators on the forward skirt to measure fuel tank ullage pressure for determination of adequate pressure for engine operation.

Failure of one EDS pressure measurement (D177 or D178) would result in a loss of data. The current design is such that one EDS measurement D177 is redundant to the other measurement D178. Additionally, fuel pump inlet pressure, measurement D2 provides essentially the same datum which can be used as additional information. These pressure measurements are not the means by which an automatic or manual abort sequence for the safety of the Apollo crew is initiated. This is accomplished via mainstage pressure switch voting logic or by an angular overrate condition initiating an automatic abort sequence during boosting phases of the S-IVB stage. The EDS pressure transducers are utilized for monitoring purposes by the astronauts to foresee troubles.

- LITTON INDUSTRIES

Potentiometer, Part Number 1A59562 (Figure 65)

The unit is installed in the Potentiometer Positioner Assembly (1A59361), which is in turn, installed in the PU Electronics Assembly (1A59358). The PU Electronics Assembly is located on the cold plates of the forward skirt.

This is a four section potentiometer. Two sections provide T/M data of mass of LH_2 or LOX. One section provides rebalance control to the bridge. The fourth section supplies an error signal to the valve control.

Ground Operations

In addition to mission failures, failure of the coarse mass section would result in the inability to load LH_2 or LOX on the S-IVB Stage.

Mission

Failure of the fine and/or coarse mass section would not result in a mission failure. There would be a loss of telemetry data. Failure of either the rebalance control section or the mass error signal section in an open or shorted condition would result in an erroneous output from the PU. The control of the J2 Engine PU valve would not be activated when required. This valve would slew to either the maximum or the minimum engine mixture ratio position depending on whether the LOX or LH_2 Pots failed and on the failure mode (open or shorted).

This would result in the inability to maintain a programmable thrust level and to have simultaneous depletion of propellants. The S-IVB Stage would, therefore, not be placed in proper orbit due to degraded engine performance, resulting in a loss of the Saturn mission.

- WAUGH

Flowmeter, Part Number 1A89104 (Figures 65 and 66)

This part is located downstream from the chilldown pump in the recirculation line. The fuel meter is located in the aft skirt area; LOX meter is on inside thrust structure area. (See N/A drawing 1A87553).

The function of the component is to measure flowrate to evaluate effectiveness of chilldown system.

Failure would result in loss of measurement and would have minimal effect on mission or ground operations. These components are used in measurements F4 and F5, and are utilized as backup for the prime measurements, J-2 engine pump inlet temperature and pressure. Fuel pump inlet temperature and pressure measurements are C3 and D2, respectively. LOX pump inlet temperature and pressure measurements are C4 and D3, respectively.

5.1.3 Ordnance Systems

The following components were discussed.

- LINK ORDNANCE

Pyrogen Initiator CDF, Part Number 1B53584 (Figure 68)

In the Saturn V/S-IVB stage, pyrogen initiators are installed in redundant pairs on the ullage rocket and retrorocket motors as mounted on the aft skirt and aft interstage, respectively.

Pyrogen Initiators are nonelectrical explosive devices employed to initiate intermediate igniters which in turn fire the rocket motors. To contain motor case combustion pressure, initiation is accomplished by explosive detonation of a fuse train through a 0.090 steel bulkhead in the pyrogen initiator.

Pyrogen initiators are employed in redundant systems designed to overcome unit discrepancy for failure to fire; however, redundancy will not overcome discrepancy in production methods and materials which could affect all parts.

Thus, in the case of the two motors in the Ullage Rocket Ignition System, failure of the pyrogen initiators to fire would cause loss of motor ignition with consequent loss of propellant positioning at the tank outlet. This would result in failure of the J-2 engine to start, would jeopardize the crew and cause loss of mission.

In the case of the four motors in the Retrorocket Ignition System, failure of the pyrogen initiators to fire would cause failure of the motors to ignite, failure of stage separation, probable loss of both mission and vehicle resulting from collision of the J-2 engine with the stage below.

- HI-SHEAR CORP.

Nut, Frangible, Part Number 1A72620 (Figure 68)

Frangible nuts are installed externally on the aft skirt of both Saturn V/S-IVB and Saturn IB/S-IVB stages in fittings designed to retain the nuts in a way that accommodates the two attach bolts of the Ullage rocket jettisonable pods.

The purpose of the frangible nuts is to secure the attach bolts of the pod against a compression loaded spring and to release the attach bolts by fracture upon command. Frangible nut fracture is accomplished by an explosive charge initiated through a fuse train.

The release function of frangible nuts is not redundant; hence, failure of a single nut to fracture after proper function of the ordnance system will result in a nonjettisoned pod weighing 65 pounds.

This represents an extra 65 pound load encroachment against the scheduled payload range which draws upon the fuel reserves of the stage at the time of J-2 engine restart. Such a load tax upon the fuel reserves, coupled with adverse tolerances expected of engine consumption, could reduce mission capability.

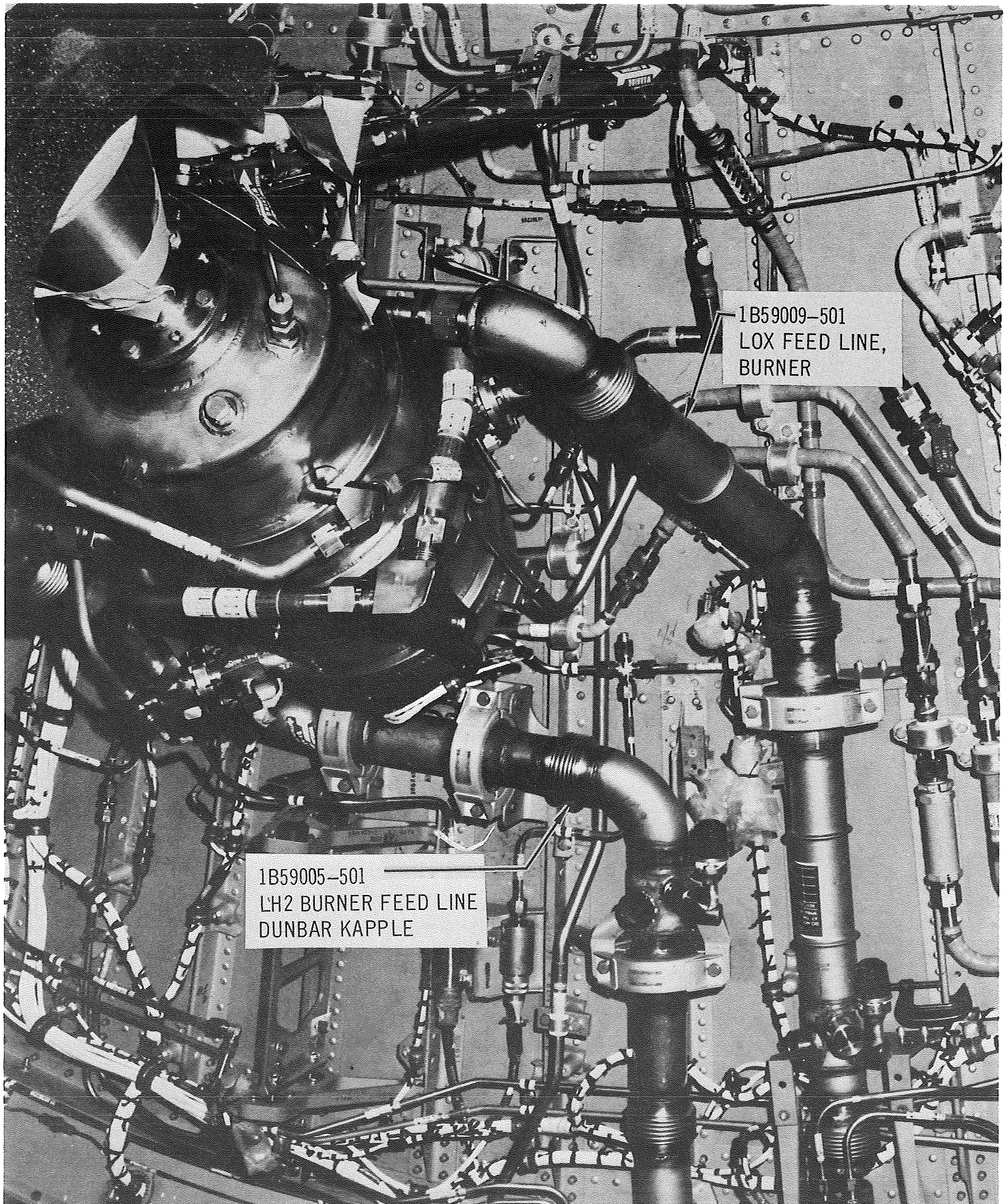


Figure 59. Burner Feed Lines

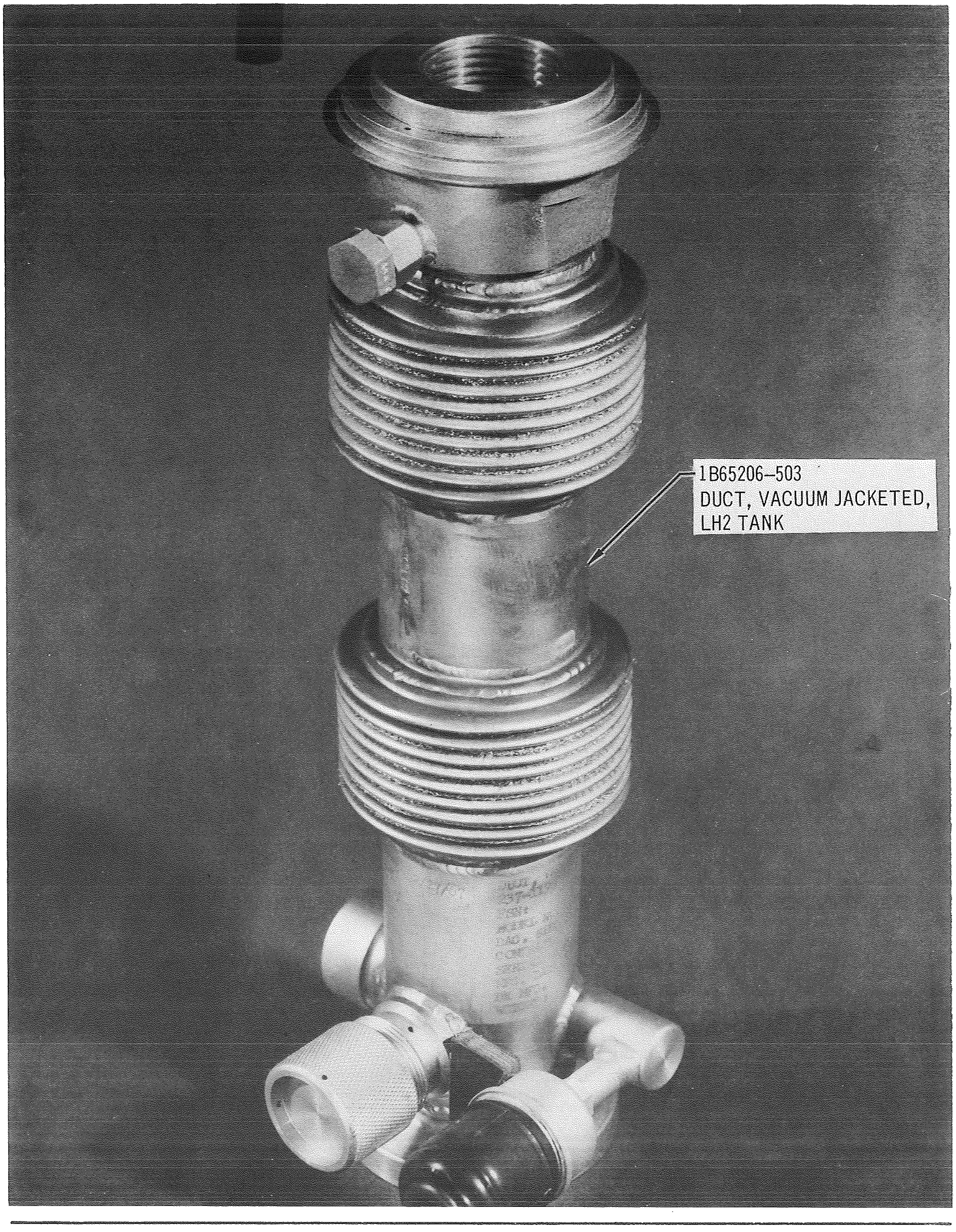


Figure 60. O2/H2 Burner Duct, Tank

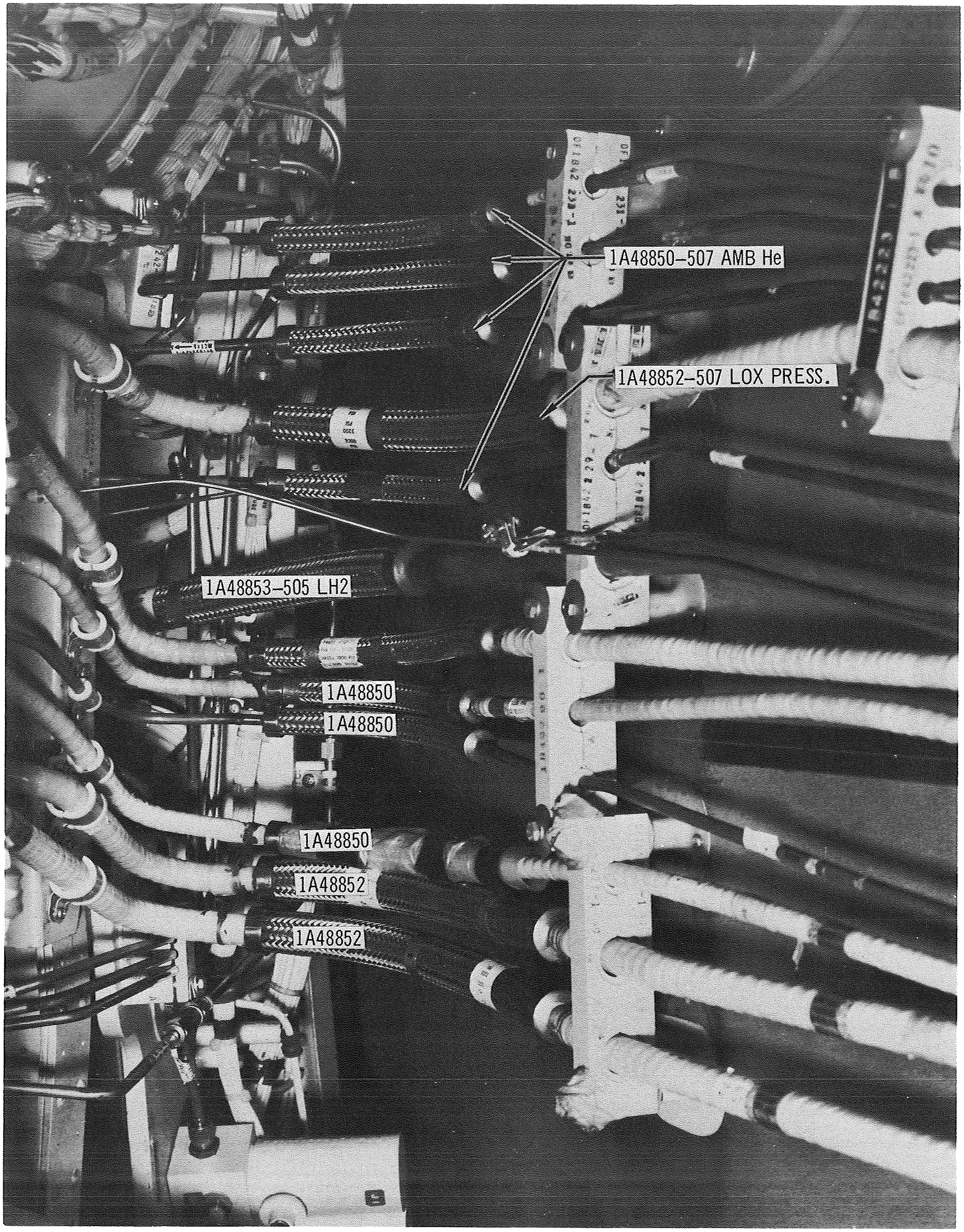


Figure 61: Anaconda Metal Hoses

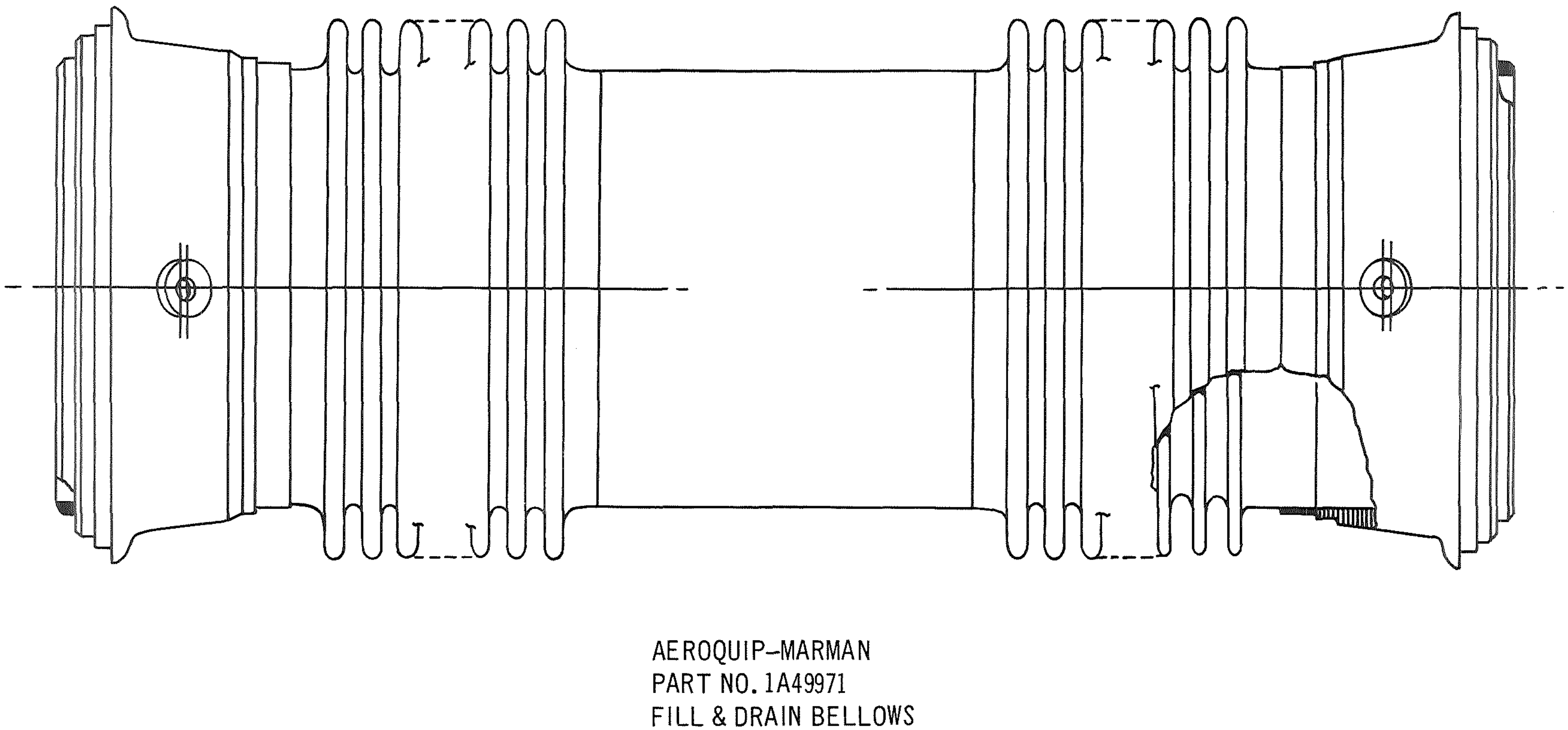


Figure 62. Fill and Drain Bellows

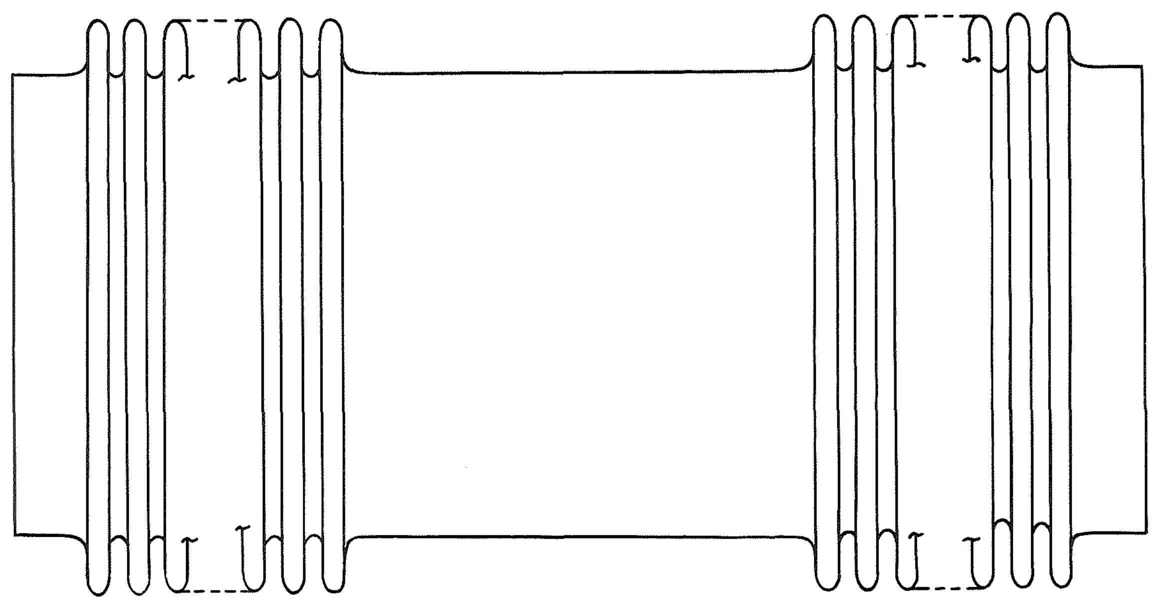


Figure 63. LH2 Fill Bellows

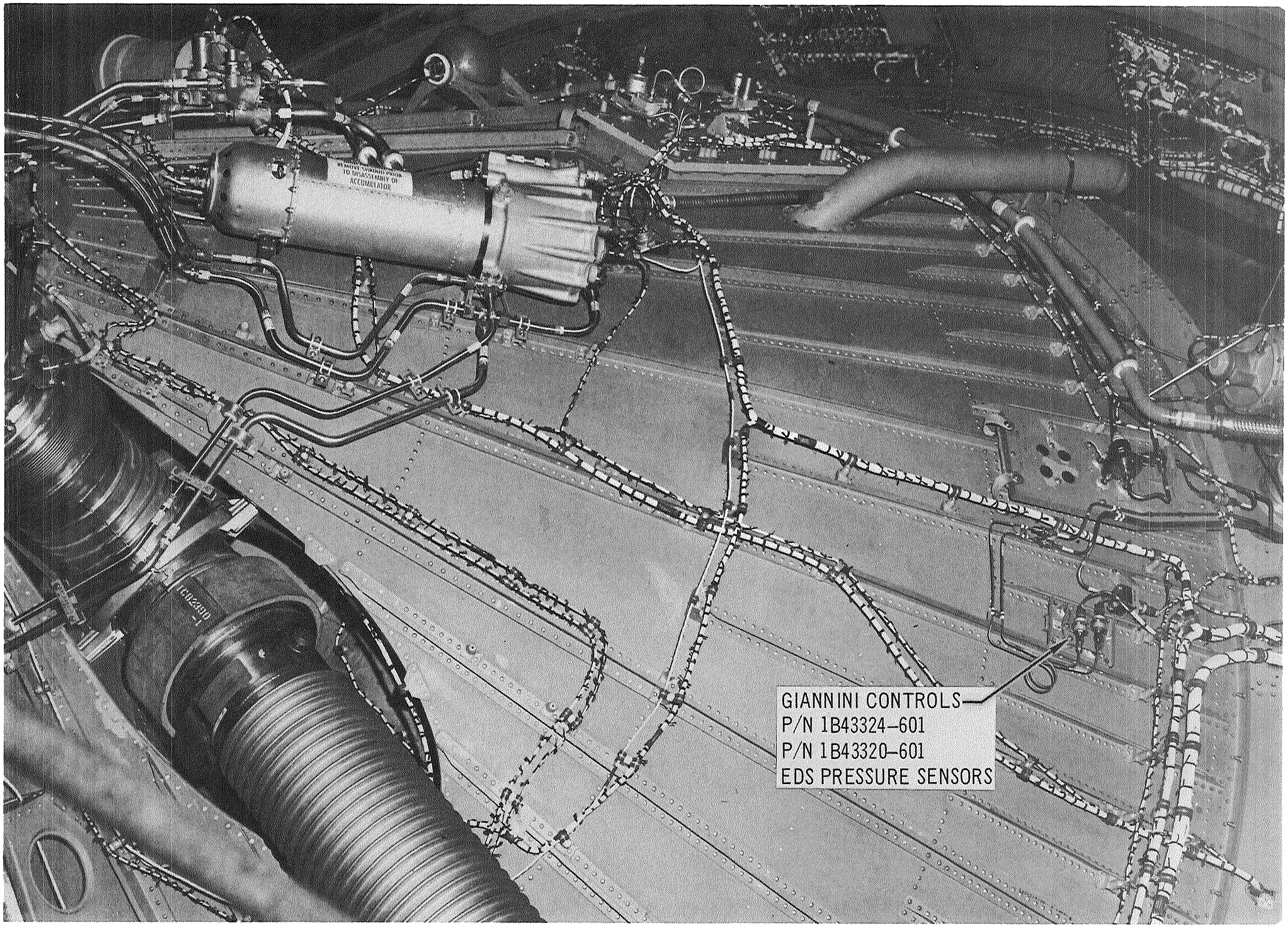


Figure 64. EDS Pressure Sensor

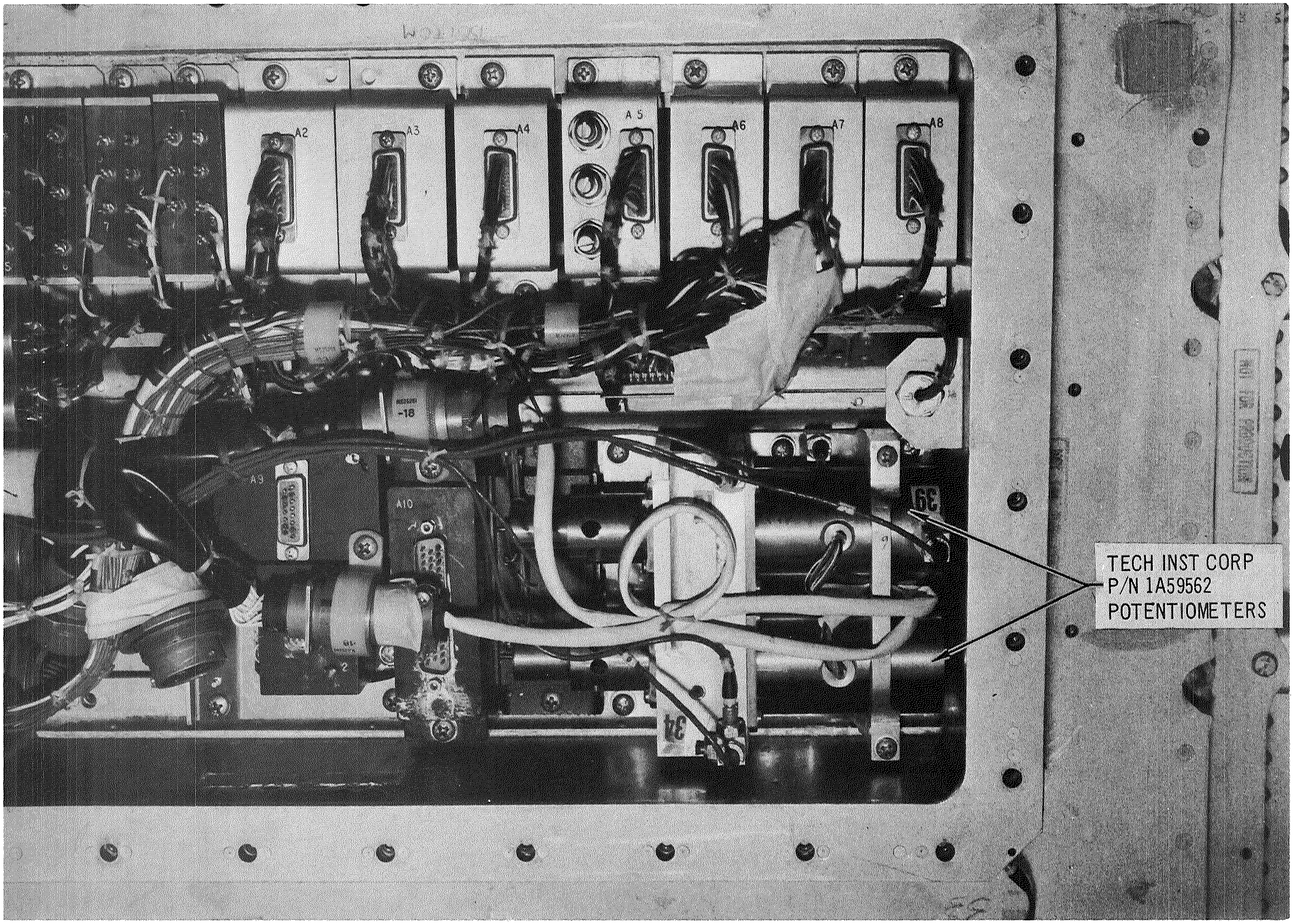


Figure 65. PU Bridge Potentiometers

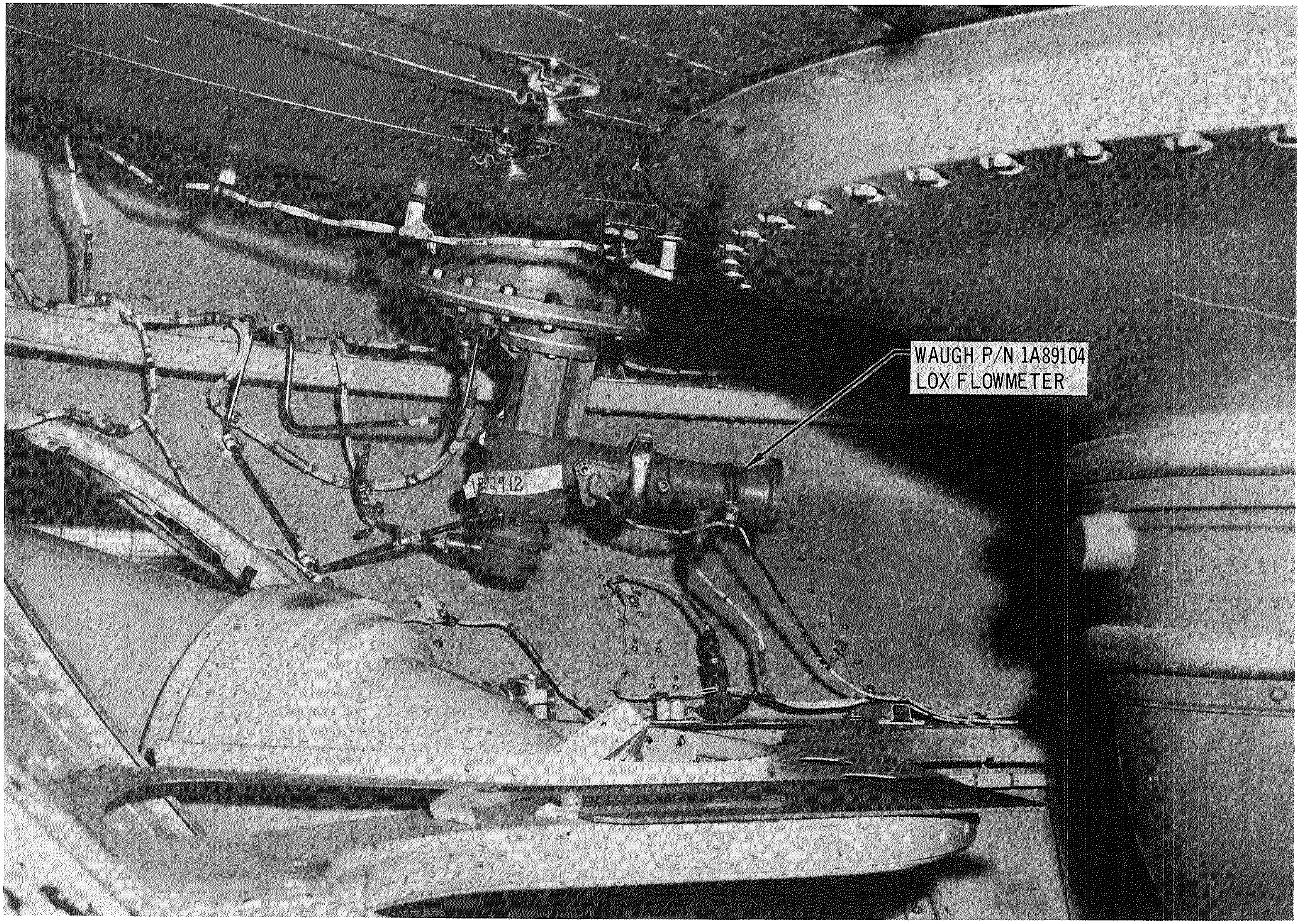


Figure 66. LOX Flowmeter

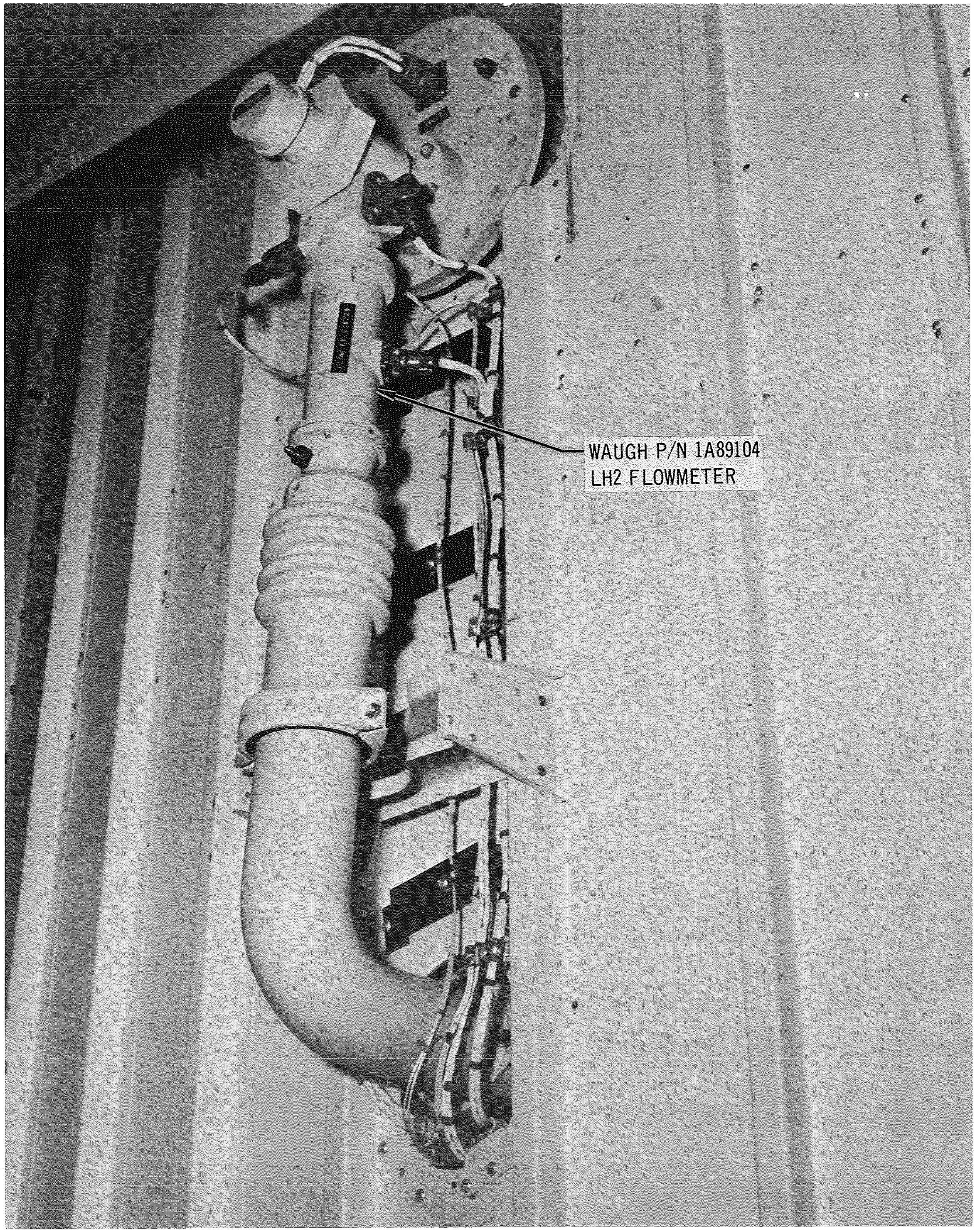


Figure 67. LH2 Flowmeter

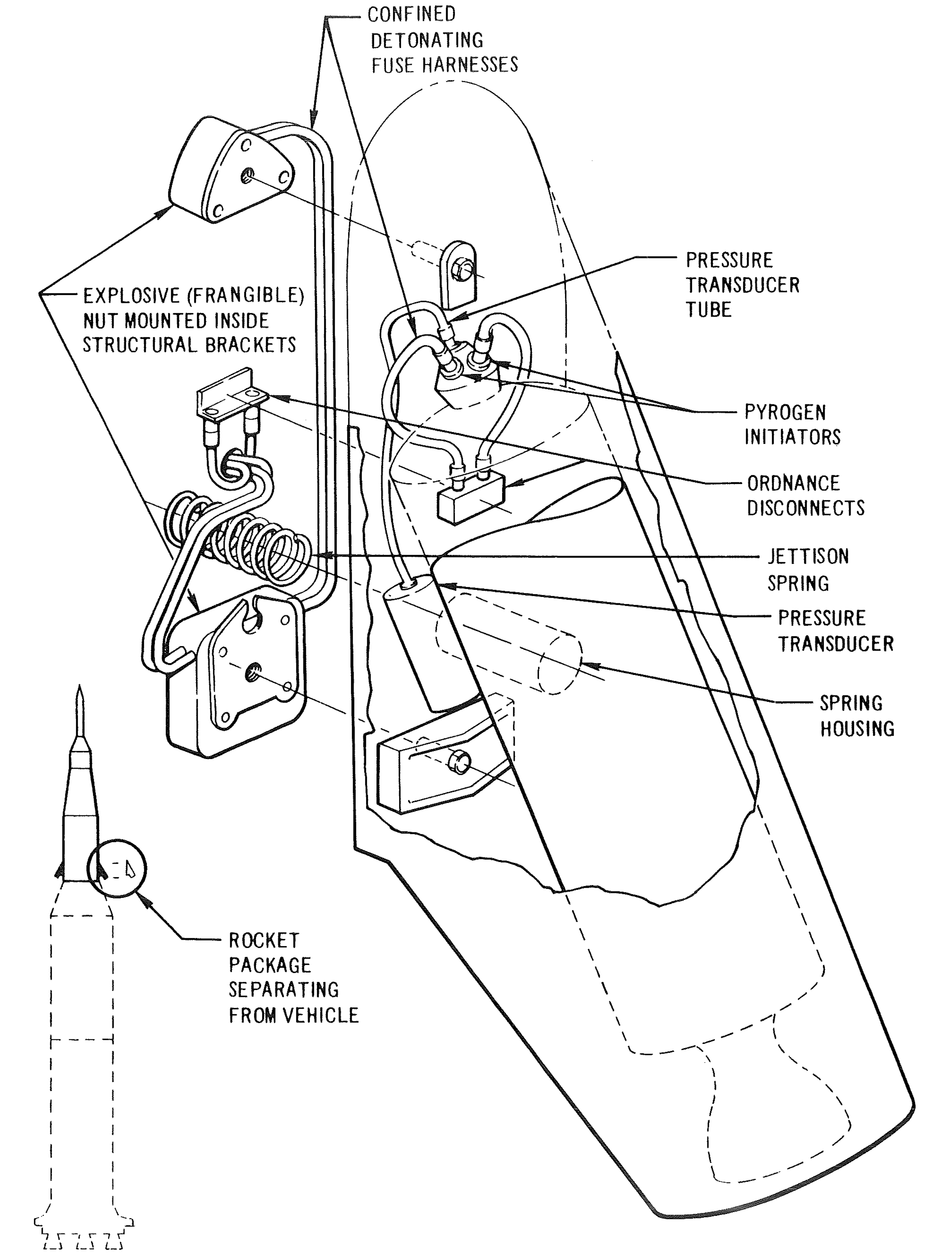


Figure 68. Ullage Rocket Installation

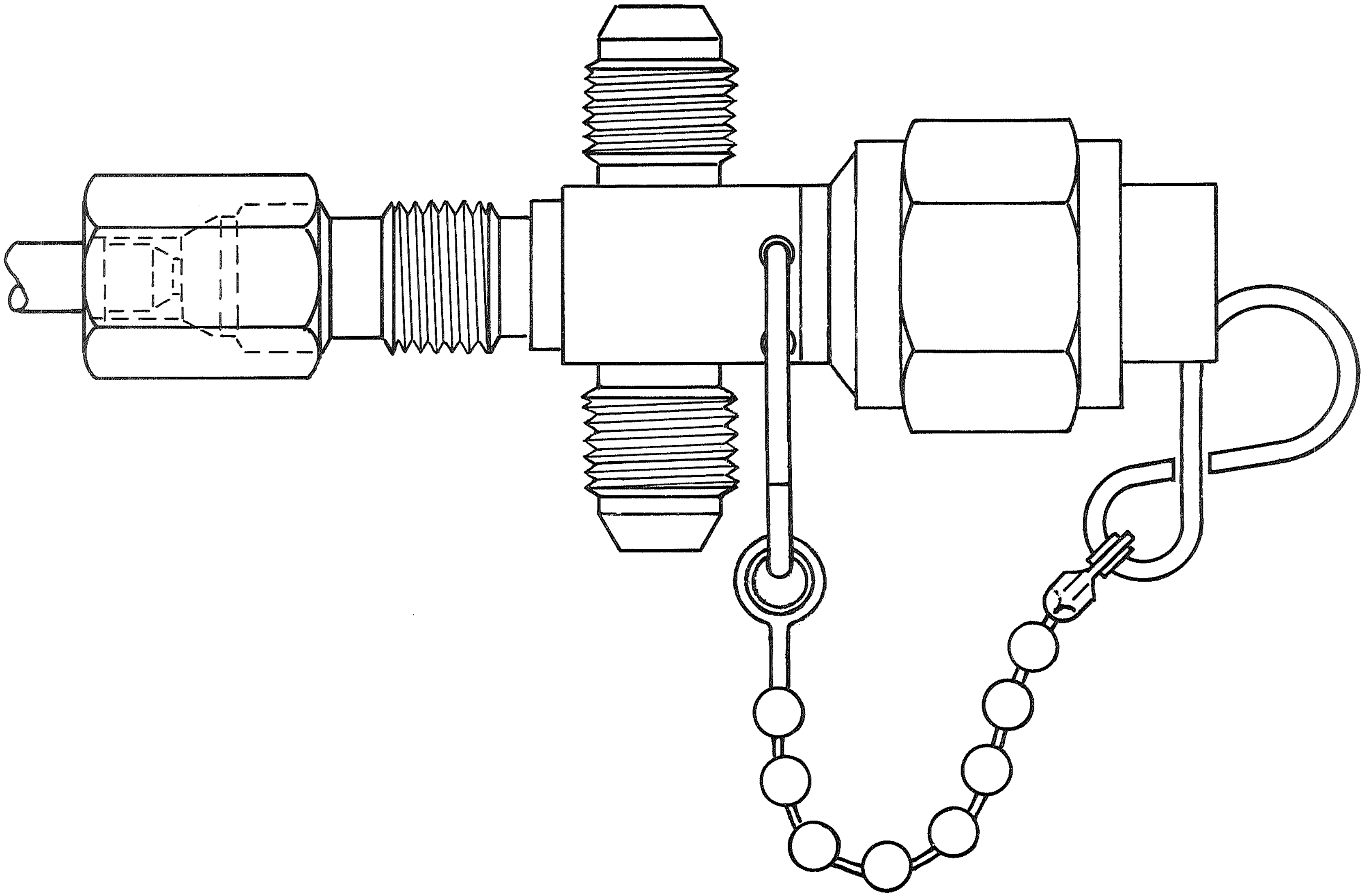


Figure 69. Randall Checkout Valve, P/N 1B53817